REPORT DOCUMENTATION PAGE

AD-A268 406

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	23 Mar 87	Final: MARCH 1987

4. TITLE AND SUBTITLE
RESEARCH AND DEVELOPMENT PRODUCTIVITY IN THE USSR: CAUSES OF DECLINE SINCE THE 1960S AND PROSPECTS FOR THE 1980S

5. FUNDING NUMBERS
C: MDA 903-85-C-0293

6. AUTHOR(S) V. Kontorovich

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Command Economies Research, Inc.
2 Sutton Lane
Princeton Junction, NJ 08550

8. PERFORMING ORGANIZATION REPORT NUMBER
87 2317

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Office of the Secretary of Defense
Office of the Director of Net Assessment
Rm 3A930, The Pentagon
Washington, D.C. 20301

10. SPONSORING/MONITORING AGENCY REPORT NUMBER
87-0687

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT
A. Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT
Examines research and development productivity in the USSR.

404 PY

14. SUBJECT TERMS
USSR R&D Productivity

15. NUMBER OF PAGES
379

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	SAR

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89
Prescribed by ANSI Std. Z39-18, 298-102

COMMAND ECONOMIES RESEARCH, INC.
a non-profit organization
2 Sutton Lane, Princeton Junction, NJ 08550
(609) 275-9535

23 March 1987

RESEARCH AND DEVELOPMENT PRODUCTIVITY IN THE USSR: CAUSES OF DECLINE SINCE THE 1960s AND PROSPECTS FOR THE 1980s.

Final Technical Report

Vladimir Kontorovich

prepared under contract
No. MDA903-85-C-0293

expiration date:
31 March 1987

Office of Net Assessment
Department of Defense
The Pentagon
Washington, D.C. 20301

Attn.: Lt. Col. Thomas Gladstone

87-0687

SUMMARY

1. Importance of R&D and its past performance.

Economic growth and military might are the two most important objectives of the Soviet government. New technology is necessary for achieving both objectives, and it is produced by the R&D sector. For this reason, research and development have long been accorded high priority by Soviet rulers. In 1951-85, R&D employment increased more than six-fold, and expenditures in current prices, by a factor of 28, much faster than total employment and national income. The most rapid expansion occurred in the late 1950s-early 1960s, with a gradual slowdown of growth afterwards. The number of scientists and engineers and expenditures in Soviet R&D far exceed those in the US.

But this phenomenal expansion of R&D did not result in proportionate growth of R&D output. The number of prototypes of new machines and instruments devloped during a year has been declining since the mid-1960s. This decline is apparent in almost all groups of machines produced by civilian machinebuilding industries, and for instruments. On the other hand, the number of prototypes of machines produced in the military machinebuilding ministries has increased. This suggests that resources have been redistributed from civilian to military machinebuilding sectors. The decline in the number of prototypes hurt the economy, where machines with obsolete design could not be replaced and many types of machines were not produced at all.

The number of patents per researcher increased in the 1960s and 1970s, but declined in the 1980s. Data on savings from implemented inventions and expert opinion indicate that the average importance of an invention has declined. The number of publications and citations also did not keep pace with expansion of the R&D sector, although this must be due primarily to administrative constraints on publishing.

These trends suggest that the productivity of R&D has declined, an assessment shared by Soviet experts.

2. Causes of decline in R&D productivity.

Decline in R&D productivity has resulted from the interaction of three elements: the desire of the Soviet leadership to have a strong and productive R&D; specific characteristics of R&D activity that make it impossible to guide through purely bureaucratic, command procedures; failure of production management to guide applied R&D through their demand for innovations.

The segment of R&D that expanded faster than the others was applied research and development subordinated to the ministries responsible for production in particular sectors. But production managers in a command economy are not interested in innovation, and hence, in the results of R&D. When the government flooded production ministries with resources earmarked for R&D, they started to engage in counterproductive practices. Research institutes were founded out of considerations of fashion and prestige, and without regard for need, availability of personnel,

designers' time. Requirements concerning the formal side of patent applications have increased. This and the increasing bias of the patent office in favor of planned inventions have squeezed out individual inventors, who usually generate the most radical ideas. New planning and management procedures implemented in the 1979s increased the burden of reporting and record-keeping on R&D personnel and led to an increase in the number of simple projects with a short payoff period, at the expense of creating radical innovations. Introduction of bonuses tied to the economic effect of implementation of innovations had the same effect. Finally, arbitrary determination of quotas for different kinds of personnel led to squeezing out technicians, blue collar workers, administrative, and clerical staff from R&D organizations; their functions have been increasingly discharged by scientists and engineers.

The dominant part of Soviet R&D, subordinated to the production ministries, has been growing increasingly unable to solve even those technological problems in which the ministries were interested. This, and the leadership's dissatisfaction with the performance of sectoral science, has led to the increasing involvement of the Academies of Sciences in applied R&D. Academies, receiving less than 10% of total R&D resources, are charged with fundamental research. The Union Academy of Sciences and some republican academies maintain high standards of research, through tradition, professional ethics, and selectivity. Their increasing involvement in direct service of the needs of

equipment, quarters, or the scientific basis for research. Managers of R&D establishments similarly expanded their fiefs as much as possible. Planning procedures themselves encouraged steady growth of inputs into R&D. Ministries diverted R&D resources to non-R&D uses, such as current production, planning and management, and all sorts of odd tasks. To the degree that ministries guided R&D, they ordered minor, routine, or trivial projects. But in many cases they did not exercise any guidance at all, leaving R&D organizations to spin their wheels, slumber, or engage in outright fraud. Being monopolistic suppliers of a particular kind of product, ministries supported the monopoly of their head R&D institutes in corresponding fields. The latter used their monopoly to hamper the work of outsiders.

With customers largely uninterested in R&D, bureaucratic rules and procedures were established as an alternative mechanism for resource allocation in this sector. But they cannot substitute for the judgment of an informed and interested user. In the best case, these bureaucratic procedures just add to the load of management and planning tasks, diverting time and energy from R&D proper. In the worst case, they further subvert R&D activity, by directing it towards routine, but easily controllable projects.

Mandatory standards regulating the appearance of drawings have been getting more demanding and have changed frequently. Designers have been required to obtain an increasing number of approvals from various organizations for their work. These bureaucratic chores have been taking an increasing slice of

production sector diverts the already limited resources away from basic research, and subjects the academies to the same influences that have trivialized applied R&D.

Debasement of sectoral R&D and the impending corruption of academic science are not the results of a policy mistake. They reflect a genuine dilemma of a command economy in the age of rapid technological progress. To benefit production, R&D must be in close touch with it. But the incentives of production sector managers are inimical to innovation, and therefore, to productive R&D. Aligning R&D closer to production hurts R&D, and in the long run benefits production very little. But to keep the two separate would not be any better.

As the R&D sector was expanding, the average salary there fell behind the average pay in industry, transport, or construction. The main cause of this was the overproduction of specialists with higher education, and shortage of workers in the economy at large. Since there were not enough workers to man all the workplaces, their salaries were rising. Since there were enough bodies to fill white-collar positions, their salaries lagged behind. Decline in relative salary coincided with (and partly, caused) a drop in the relative prestige of the occupations of scientists and engineers. While we cannot demonstrate this empirically, the decline in relative salary and prestige must have caused a decline in the average ability of entrants into R&D. It also has caused the increased feminization of R&D. Many R&D occupations have come to be regarded as quiet and unstressful

havens for second-salary earners burdened with domestic chores.

A large part of Soviet R&D is very badly equipped (to the point of having no equipment at all). It is not clear whether this situation has deteriorated or improved with time.

The decline in R&D productivity has occurred despite a number of positive trends: the increasing education level of scientists and engineers; the increasing share of technical and natural sciences in the R&D total; and the increased importation of knowledge from abroad.

3. Forces that will shape R&D productivity in the future.

The past slide of R&D productivity was related to the rapid inflow of resources into this sector. Since the expansion of R&D is over, these past causes of deterioration are no longer active. Moreover, as gross abuses of the past become more visible, they may be set straight, improving R&D productivity. However, the structure underlying the past decline in productivity remains intact. Customers of applied R&D are still at best indifferent to innovation; bureaucratic guidance has to substitute for lack of guidance by the customers. This will insure that any improvement to R&D productivity will be minor. For example, the most egregious requirements for obtaining approvals for designs are now being cancelled, and standards for presentation of drawings are being simplified. But this simplification cannot go too far without endangering coordination in the economy and setting irresponsible designers free to harm indifferent customers.

Current economic reforms do not make firms or ministries more interested in innovations. The ambitious output targets of the current five-year plan, coupled with the discipline drive, will force ministries to scurry everywhere for resources, and will reinforce their usual anti-R&D behavior pattern. With the structure underlying poor R&D productivity intact, there is no reason to expect that this sector will radically improve its performance.

In fact, the recent stabilization of the size of R&D sectors has given rise to two new forces depressing R&D productivity: aging of research agenda and aging of researchers. Rigidity of organizational structure, security of tenure, and large degree of discretion in the choice of projects exercised by Soviet scientists result in perpetuation of topics, projects, or directions of research. Nobody willingly abandons an obsolete, fruitless, or exhausted topic, and few are forced to do so. The way to start new projects and directions of research is to found a new institute or department. But establishment of new organizations and units is now tightly restricted, and mechanisms for switching available resources to new topics are not in place. This means that the total portfolio of research projects will be dominated by older, more exhausted topics, as incumbent scientists continue their old topics, and new entry is minimal.

Another problem of slow growth is the aging of researchers. The single largest cohort, that hired during the height of expansion in the late 1950s-early 1960s, is entering the period

of declining individual productivity. With vacancies limited by essentially frozen salary funds, R&D is going to be dominated by the older, less productive people.

4. Policies and prospects for R&D productivity.

Gorbachev has enacted relatively radical policies and has promised an injection of investment to revive R&D. This has further hightened the priority of what seemed to be already the top priority sector. The reasons for this are the need to accelerate economic growth and to safeguard the status of the Soviet Union as a great nation in the face of SDI.

Increased investment will increase productivity in R&D, to the degree that it materializes. This requires that the government sticks to its target as the 12th five-year plan for investment unravels; that ministries, pressed to show output growth, do not divert investment earmarked for R&D to create production capacity, and do not use newly built experimental and pilot production facilities for routine production tasks. These behavior patterns have predominated in the past, and can be expected to emerge again.

Regulations allowing greater flexibility in remuneration and firing will bring only marginal improvements, for R&D managers lack compelling reasons to utilize this new flexibility. The policy of closing down unproductive institutions has so far only been applied to the most egregious cases of fraud and wheel-spinning, and has been conducted on too small a scale to make a

major impact on productivity.

Other current reforms will have strong adverse effects. Mergers of R&D organizations with industrial enterprises will further channel their efforts into minute projects, and allow enterprise managers to divert their resources to non-R&D purposes. The increasing involvement of the academies in applied research, development, implementation, and even small-scale production of their innovations diverts already meagre resources from fundamental research, and subjects the best scientific organizations of the country to the corrupting influence of industry, with its lack of interest for radical innovations. Debasement of academic science by trivial applied projects will be a major blow to Soviet R&D.

Current policies and reforms do not address the most dangerous trends in R&D: the aging of the research portfolio and the aging of researchers. All measures taken so far in these areas have either been ineffective, or minor.

Current reforms will stabilize, and possibly somewhat increase, measured R&D productivity in the short run, if only through the shock of change. But the reforms do not introduce a mechanism for continuous improvement in R&D productivity. The short-run increase in measured R&D productivity will be in part achieved through dilution of real R&D productivity (diversion of resources from fundamental research and from long-payoff-period projects to simpler ones). Real R&D productivity will be further damaged as the aging processes slowly unfold.

One direction of the current policy is to make Soviet R&D abandon imitation of Western technology, and undertake original pioneering research instead. Imitation of Western technology is another substitute for the missing guidance of R&D by the domestic production sector. Imitation perpetuates the lag of Soviet R&D behind that of the West. It is not always rational, because the needs of Soviet users may be quite different from those in the West. Still, the imitation strategy cannot be abandoned before Soviet industry itself begins to care about new technology.

Table of Contents

Section . . . . page

List of Tables xvi

List of Abbreviations xxi

Acknowledgements xxiii

PART I. SETTING THE STAGE 1

Chapter 1. The Problem of R&D Productivity. 1

1.1 The importance of R&D sector. 1
1.2 Performance of R&D sector. 4
1.3 Soviet R&D sector in international prospective. 9
1.4 The objectives of this study. 20

Chapter 2. How Advances in Knowledge Are Produced. . . 21

2.1 R&D: inputs and outputs. 21
2.2 Institutionalized domestic R&D and other sources of new knowledge. 23
2.3 Relation between inputs and outputs. 24
2.4 Measurement of inputs and outputs. 27

Chapter 3. Institutional Background. 30

3.1 Boundaries of the sector. 30
3.2 Three systems of R&D. 33
3.2.1 Academies. 33
3.2.2 Sectoral science. 36
3.2.3 Teaching institutions. 37
3.3 People. 39
3.3.1 Definitions of employment. 39
3.3.2. Ranks and degrees. 40
3.4 R&D organizations. 41
3.4.1 Types of establishments. 41
3.4.2 Inside an institute. 49
3.5 Planning and direction of R&D. 53
3.5.1 Central planning and management: organs and procedures. 53
3.5.2 Plan targets of establishments. 57
3.5.3 Planning within an establishment. . . . 60
3.5.4 Economic incentives. 65
3.5.5 Financing. 66

3.6 Changes in organization and planning. . . 69

PART II. OUTPUTS. 72

Chapter 4. Prototypes of New Equipment. 72

4.1 What is a prototype? 72
4.2 Creation of prototypes. 74
4.2.1 General trends. 74
4.2.2 Machines, equipment, and apparatus. . . 76
4.2.3. The mysterious residual. 81
4.2.4 Instruments, computers, means of automation. 89
4.3 The lack of prototypes hurts the economy. . . 92
4.3.1 The number of prototypes limits the number of new models produced. 92
4.3.2 The economy needs more new models of machines 99
4.3.3 There are too many models of similar equipment. 102
4.4 Conclusion. 104

Chapter 5. Inventions. 108

5.1 Trends in patenting. 108
5.2 Changes in the weight of an average invention. 112
5.2.1 Qualitative evidence. 113
5.2.2 Economic effect of implemented inventions. 114
5.3 Conclusion. 118

Chapter 6. **Other Measures of Output**. 119
6.1 Publications. 119
6.2 Citations. 121
6.3 Economic effect of implemented R&D. 122
6.4 Discoveries. 122

PART III. CAUSES OF PRODUCTIVITY DECLINE: GIVING RESOURCES TO THOSE WHO CANNOT CONTROL THEIR USE. 125

Chapter 7. Bureaucratic expansionism. 126

7.1 Expansionism at the top. 127
7.2 Expansionism at the bottom. 130

Chapter 8. Increasing share of sectoral R&D. 132

8.1 Trends in the shares of resources of the three

systems of R&D. 132
8.2 Why sectoral R&D was given priority. 137
8.3 Objectives of ministries and utilization of R&D resources. 138
8.4 What ministries actually have done with R&D resources. 141
8.4.1 Diversion of resources to non-R&D uses. 141
8.4.1.1 Extension of the administrative apparatus under the guise of R&D. . 141
8.4.1.2 Diversion of investment resources and capacities intended for experimental facilities. . . . 144
8.4.1.3 Use of R&D personnel in physical work. 148
8.4.2 Misdirection of R&D effort. 149
8.4.2.1 Increase in the share of development and of minor projects. 149
8.4.2.2 Creating R&D organizations in the sectors without a scientific basis. 152
8.4.2.3 Unproductive and fraudulent institutions. 154
8.4.2.4 Monopoly of head institutes. . . 155
8.5 Conclusion: weakening of sectoral science. . . 158

Chapter 9. Bureaucratization of R&D. 160

9.1 Bureaucratization of design. 160
9.1.1 Standardization. 160
9.1.2 Obtaining approvals. 164
9.2 Bureaucratization of inventive activity. . . . 167
9.2.1 The decline of the individual inventor. 167
9.2.2 The causes of decline of the independent inventor. 170
9.2.2.1 General bias of the patent office. 170
9.2.2.2 Difficulties in getting royalties. 171
9.2.2.3 Increasing requirements to patent applications. 172
9.2.3 The rise of planned invention. 174
9.3 Innovations in planning and organization of sectoral R&D. 175
9.3.1 <u>Minelektrotekhprom</u> system. 175
9.3.2 Programs. 179
9.4 Increasing overhead in R&D. 179
9.5 "Scientific bias". 181
9.5.1 Research versus development. 181
9.5.2 Researchers versus support personnel. 184

Chapter 10. The Academy becomes more applied. 191

10.1 Why the Academy is stronger than other systems of R&D. 191
10.2 Difficulties in cooperation between the Academy and sectoral R&D. 192
10.3 Getting the Academy to do the work of sectoral R&D. 194
10.4 Increasing share of applied research and development in the Academy's work. 196
10.5 Subverting the excellence of the Academy. . . 198

PART IV. OTHER CAUSES OF PRODUCTIVITY DECLINE AND COUNTERVAILING FACTORS. 200

Chapter 11. Expanding R&D on the cheap: labor. 200

11.1. Salary in R&D declines relative to the other sectors. 200
11.1.1 The data. 200
11.1.2 Causes of the decline. 205
11.2 Declining prestige of R&D jobs. 206
11.3 Consequences of decline in relative salary and prestige. 208
11.3.1 Decline in ability of entrants. . . . 208
11.3.2 Feminization of R&D personnel. 210
11.3.2.1 Productivity of women in R&D. . 210
11.3.2.2 The share of women in R&D. . . 212

Chapter 12. Expanding R&D on the Cheap: Equipment. . . 217

12.1 Qualitative evidence on lack of equipment and buildings. 217
12.2 Expenditures on non-labor inputs. 221
12.3 Expenditures on equipment. 224
12.4 Investment in R&D. 231
12.5 Fixed capital in R&D. 233
12.5.1 Stock of capital. 233
12.5.2 Services of capital. 237
12.6 Summary. 239

Chapter 13. Problems of slow growth. 241

13.1 Ossification of the resarch agenda. 242
13.2 Aging of researchers. 243

Chapter 14. Countervailing trends. 251

14.1 Declining share of higher learning institutions. 251
14.2 Increasing share of technical sciences. . . . 257
14.3 Increase in educational level. 260
14.4 Increase in the importation of knowledge. . . 263

14.5 Non-R&D components of R&D have been growing slower than R&D proper. 265
14.6 Shift to more applied research. 266

PART IV. POLICIES AND PROSPECTS. 269

Chapter 15. Gorbachev's reforms for R&D sector. 269

15.1 Soviet awareness of problems in R&D. 269
15.2 Greater allocation of resources and more flexibility in their use. 270
15.2.1 Increasing expenditures and investment. 271
15.2.2 Making remuneration of scientists and engineers more flexible. 274
15.2.3 Closing down institutions. 280
15.2.4 Supply reform. 281
15.3 New (and not so new) organizational forms. . 282
15.3.1 Associations (POs) and science-production associations (NPOs). 283
15.3.2 Intersectoral complexes and engineering centers. 288
15.3.3 Temporary units. 293
15.4 Reform of higher education. 294

Chapter 16. Prospects for R&D productivity. 300

16.1 The underlying structure. 300
16.2 Determinants of R&D productivity that no longer matter. 302
16.3 Determinants of R&D productivity that will be important in the future. 304
16.3.1 Determinants pushing R&D productivity higher. 304
16.3.2 Determinants depressing R&D productivity. 309
16.4 Can the imitation strategy be abandoned? . . 311
16.5 Summary. 313

APPENDIX A. Data and definitions. 314

A.1 Definition of R&D sector. 314
A.2 R&D employment 316
A.3 Science workers: degree and rank. 318
A.4 Expenditures: definitions and scope. 323
A.5 Sources of financing. 326
A.6 Allocation of resources by stage of R&D. 328
A.7 Time lags between inputs and outputs. 333
A.8 Prototypes of new equipment. 334

A.9 Researchers and support personnel in the Academies of Science. 337

APPENDIX B. Rejected hypothesis: shifts in regional structure of R&D as a cause of the productivity decline. 339

B.1 Regional differences in R&D productivity. 339
B.1.1 Why R&D productivity differs by region. . . 339
B.1.2 Data on productivity differences. 340
B.2 The structure of republican R&D. 343
B.3 Trends in allocation of resources among republics . 348

APPENDIX C. SOURCES AND TABLES. 356

BIBLIOGRAPHY 362

List of Tables

Table 1-1. Growth of R&D sector, annual growth rates, %. 5
Table 1-2. Inputs into R&D as a share of national resources, %. 6
Table 1-3. Productivity in R&D, 1951-85. 8

Table 2-1. Structure of R&D output by type of product in 1971, shares, %. 28

Table 3-1. Distribution of institutions and science workers in the Academies by type of establishment, end of 1973. 42
Table 3-2. Science institutions by type, end of 1955. 43
Table 3-3. Average number of science workers per institution of Union and republican Academies, end of 1973. 44
Table 3-4. Number of R&D units at 44,111 industrial enterprises (beginning of 1973). 46

Table 4-1. Number of prototypes created, units & growth rates,%. 74
Table 4-2. Number of prototypes of machines and instruments created, and their growth by five-year periods, %. 76
Table 4-3. Number of prototypes of machines and equipment by five-year periods. 78
Table 4-4. The timing of peaks of machine prototypes created, by group. 79
Table 4-5. Total, itemized, and residual numbers of prototypes of machines, equipment, and apparatus. 85
Table 4-6. Growth rates of total, itemized, and residual prototypes of machines and equipment by five-year periods, %. 86
Table 4-7. New types of instruments created. 90
Table 4-8. Structure of instruments prototypes, shares, %%. 91
Table 4-9. Prototypes accepted for production as a share of prototypes created, %. 92
Table 4-10. Prototypes put into production as a share of all prototypes created, %. 93
Table 4-11. Rates of growth of the number of new models put into production, % (by five-year periods and annual). 95
Table 4-12. Number of new models of machines put into series production as a share of prototypes created, by type, %. 96

Table 5-1. Patent applications, patents granted, and rate of approval of applications. 110
Table 5-2. Periodization of trends in inventive activity. 111
Table 5-3. Average economic effect per implemented invention, rubles. 117

Table 6-1. Scientific books and brochures published. 119

Table 6-2. Scientific and technical books, by discipline. 120
Table 6-3. Discoveries. 123

Table 8-1. Science workers in three systems of R&D, shares, %. 134
Table 8-2. Science workers in sectoral R&D as a share of all science workers, %. 135
Table 8-3. Expenditures by sector of R&D, shares, %%. 136
Table 8-4. Distribution of sectoral NII and KB by the main direction of their work, shares of the total number of institutions in the sector, %%. 144
Table 8-5. Share of research projects in the total volume of projects in Minpribor, %. 150
Table 8-6. Average annual R&D employment by sector, index, 1969 = 1. 152
Table 8-7. Distribution of R&D employment and science workers by sector of economy in Moscow in 1978, shares, %. 154
Table 9-1. Relative decline of independent inventor. 168
Table 9-2. Absolute decline of independent inventor. 169
Table 9-3. Employment by type of R&D organization, thousands. 181
Table 9-4. Science workers and research personnel in the USSR. 185
Table 9-5. Engineers and technicians in science and science services. 185
Table 9-6. Science workers as a share of R&D employment, %%. 186

Table 10-1. Share of contract work in total expenditures of Academies, %. 197
Table 11-1. Average money monthly wage in science and science services compared to other sectors, %. 201
Table 11-2. Shares of employees with higher and special secondary education in sectoral labor, %. 202
Table 11-3. Shares of employees with higher (H) and special secondary (Ss) education in sectoral labor force, %. 202
Table 11-4. Average monthly wages, rubles. 203
Table 11-5. Changes in evaluation of prestige of R&D occupations over 20 years in Novosibirsk, 1983 as a % of 1963. 207
Table 11-6. Sex Structure of Science Workers, and of their groups by rank and degree, shares, %. 213
Table 11-7. Share of women in science and science services, %. 214
Table 11-8. Education of R&D employees by sex, shares, %%, 1959. 215

Table 12-1. Non-wage science expenditures. 222
Table 12-2. Non-wage expenditures per employee in R&D, average annual growth rates, %. 223
Table 12-3. Material inputs per employee in R&D, average annual growth rates, %. 224

Table 12-4. Structure of science expenditures (excluding investment) in 1965-1968, shares, %%. 225
Table 12-5. Change in the share of equipment and salary in total R&D expenditures (1970 = 1) 226
Table 12-6. Growth of expenditures in the Union Academy, 1966-1975, %. 227
Table 12-7. Expenditures and their structure in Ukrainian Academy, growth, %. 228
Table 12-8. Structure of expenditures in the Union Academy, shares, %%. 228
Table 12-9. Structure of expenditures in Ukrainian and Bielorussian Academies, shares, %%. 229
Table 12-10. Shares of different fields in total equipment purchases in Ukrainian Academy, %%, 1960-1965. 230
Table 12-11. Investment in R&D. 231
Table 12-12. Technological structure of R&D investment, shares, %. 232
Table 12-13. Share of experimental and testing facilities in R&D investment, %. 232
Table 12-14. Fixed capital stock: structure and volume. 233
Table 12-15. Fixed capital in science and science services. 234
Table 12-16. Fixed capital stock in science and science services: growth and structure. 235

Table 13-1. Changes in age distribution of science workers, shares, %%, 1959. 245
Table 13-2. Changes in age distribution of doctors and candidates of science, shares, %. 245
Table 13-3. Average age of researchers in the Union Academy, years. 246
Table 13-4. Aging of researchers in Ukrainian Academy. 247
Table 13-5. Age and ability to choose one's projects, rated on 1 to 7 scale. 248

Table 14-1. Estimates of the higher learning institutions' share of science workers and R&D work performed in the late 1970s-early 1980s, %. 252
Table 14-2. Research performed at teaching institutions. 256
Table 14-3. Structure of science workers by field, shares, %. 258
Table 14-4. Education of employed in science and science services, shares, %%, 1959. 261
Table 14-5. Education of R&D employees, shares, %%. 262
Table 14-6. Employment in science and science services by subsector, shares of the total, %%. 265
Table 14-7. Contract financing of R&D in higher learning institutions, %. 267

Table 15-1. Planned growth of R&D expenditures. 272

Table A-1. Science workers: number and growth. 319

Table A-2. Structure of science workers by degree and rank, shares, %. 320
Table A-3. Non-overlapping classification of science workers by rank and degree for October 1, 1956. 321
Table A-4. Science workers without degree and rank. 322
Table A-5. Share of budget outlays in total science expenditures, %%. 327
Table A-6. Structure of financing of sectoral R&D, shares, %%. 328
Table A-7. Structure of financing in sectoral science establishments, shares, %. 328
Table A-8. Expenditures by stage of R&D, shares, %. 329
Table A-9. Detailed characterization of R&D stages in 1971. 330
Table A-10. Employment in basic research (science workers?), thousands. 331
Table A-11. Time spent by researchers by stage of R&D. 332
Table A-12. Breakdown of time spent on different stages of R&D, in % shares of total number of science workers. 332
Table A-13. Time lags between R&D expenditures and results in machinebuilding, years. 334
Table A-14. Duration of R&D projects by sector in 1969-1970, years. 334
Table A-15. Employment in Ukrainian academy of sciences, shares and growth rates, %%, on Jan. 1. 337
Table A-16. Structure of personnel of Bielorussian Academy of Sciences, shares, %%. 337

Table B-1. Inventive productivity of science workers by republic in 1976. 342
Table B-2. Science workers in academies as a share of all science workers by republic, %%. 344
Table B-3. Distribution of science workers in scientific disciplines by republic, end of 1972, shares, %%. 347
Table B-4. Distribution of science workers in republics by scientific discipline, end of 1972, shares, %%. 348
Table B-5. Distribution of R&D employment by republic, shares, %%. 349
Table B-6. Distribution of science workers by republic, shares, %. 350
Table B-7. Distribution of science workers by republican academies, shares, %%. 352

Table C-1. Science workers - women, thousands, year-end. 357
Table C-2. Science workers by degree and rank, thousand, year-end. 358
Table C-3. The number of samples of new machines, equipment, and apparatus created per year by group. 359

List of Abbreviations

AN - Academy of Sciences of the USSR.

CC - Central Committee of the Communist Party of the USSR.

CM - Council of Ministers of the USSR.

EFRNT - Unified fund for development of science and technology, formed at the sectoral ministries from central budget allocatiosn and levies from enterprises, to finance all R&D in the sector.

GKNT - State committee for science and technology.

Glavk - Main administration of a ministry, responsible for a subsector (e. g., knitten goods within light industry, or a function (e. g., planning). During the 1970s, many glavks were rechristened "industrial associations".

Gosplan - State planning committee.

Gosstroi - State committee for construction.

KB - Design bureau

khozraschet - "economic accounting", a system when organization has to cover its outlays out of receipts, as opposed to being financed by a state budget allocation.

MBMW - machinebuilding and metalworking sector.

Minelektrotekhprom - Ministry of electrotechnical industry.

MNS - Junior scientific worker, scholarly rank.

NII - Scientific research institute, main type of research institution in a sector of economy.

NKh - Soviet statistical yearbook Narodnoe khoziaistvo SSSR v

... g., published in Moscow by Statistika (recently, Statistika i finansy).

NPO - science-production association, a merger of R&D organizations with production enterprises headed by the former.

PKTI - project-making, design, and technological insitute.

PO - production association, a merger of R&D and production organizations headed by the latter.

PTI - project-making and technological insitute.

SNS - Senior scientific worker, scholarly rank.

SO AN - Siberian Division of the AN.

TsSU - Central Statistical Administration.

TsZL - central plant laboratory.

VAK - Higher Attestation Commission, awarding scholarly degrees and ranks.

VUZ - higher education institution (polytechnic, university, etc.)

Acknowledgements

This report has beenfited enormously from the participation of two consultants, Herbert Levine and Vladimir Shlapentokh. Richard Ericson focused my attention on speciifc characteristics of R&D that are important for understanding of the Soviet case. I would like to thank Aron Katsenelinboigen, Jacob Schultz, and John Young for comments that resulted in a number of important improvements.

PART I. SETTING THE STAGE

Chapter 1. The Problem of R&D Productivity.

1.1 The importance of R&D sector.

Economic growth and military might are the two most important objectives of the Soviet government. New technology is necessary for achieving both objectives, and it is produced by the R&D sector. For this reason, research and development have long been accorded high priority by Soviet rulers.

In the 1970s and early 1980s, technological progress occupied the leading place in policy pronouncements.[1] Gorbachev further heightened the priority of what already seemed to be the top priority issue. There are several reasons for this. One is the need to accelerate economic growth. In the 1970s-early 1980s technological progress, instead of propping up economic growth rates, has been one of the causes of their decline.[2] Another reason is formulated as the need to safeguard the status of the Soviet Union as a great nation. This means maintaining a powerful military posture. In the face of SDI, this requires access to the most advanced technology. Finally, despite becoming a scientific superpower (every fourth scientist in the world is Soviet, as Soviet authors put it), the country is still lagging

[1] See Kontorovich, 1985, pp. 178-9.

[2] Kontorovich, 1986, pp. 181-3.

behind the capitalist world in its technological level, and has to imitate, buy, and steal the most advanced technology from abroad.[3]

With the increased stress on technological progress comes the increased importance of its source: the R&D sector. This is reflected in funding decisions and intensive reorganization of the sector, undertaken by Gorbachev.

Is Soviet leadership correct in viewing the R&D sector as holding the answers to its problems? R&D does not immediately effect technological change, it only creates the potential for it. E. g., the R&D sector produces a model of a new machine; it is left to the production sector to start making and using it. Technological advance is held back primarily by the economy's unwillingness to use the results of R&D - in other words, to innovate.[4]

Thus, heads of several academic institutes estimate that 20-50% of their results are not being implemented into production. Out of the 188 most important proposals stemming from research undertaken by the Academy of Sciences on its own initiative and submitted to Gosplan, only 108 were adopted for

---

[3]This is now openly acknowledged by the Soviet officials and journalists: Silaev, 1986; V. Trapeznikov in Pravda, March 20, 1980 (quoted in Rassokhin, 1985, p. 222); Kovalenko, 1986; Rudoi, 1986.

[4]Berliner, 1976, is devoted to the analysis of this issue. See also Ekonomika i organizatsiia promyshlennogo proizvodstva, no. 4, 1982, p. 43.

execution.[5] In the early 1970s, the Ministry of Chemical Machinebuilding was implementing only 8% of all inventions patented by its subordinate organizations, and the Ministry of Instruments and Computers, only 17%.[6] The situation is even worse with diffusion of innovations: 85% of all innovations are implemented at 1 or 2 enterprises, and only 1-2% at five and more enterprises.[7]

But this and similar evidence does not absolve the R&D sector from responsibility for technological change. First, many results of R&D overcome resistance of production managers and are implemented. The quality of these innovations depends to a large degree on the performance of R&D. Second, resistance to innovation is not uniform through the production sector. It is the strongest at the existing civilian plants with series production technology for projects accorded low priority by the political leaders. The risk of disrupting the flow of current production is the main motive in this case. But even here, one encounters plenty of cases when the fault lies with the R&D sector: e. g., the R&D sector offers innovations which are not sufficiently developed and tested, or do not correspond to the needs of

---

[5]Bliokov, 1984, pp. 37-8.

[6]Naiashkov, 1976.

[7]Anchishkin, 1986, p. 366. See also the speech by the then-President of the Academy of Sciences, A. P. Aleksandrov, at the 27th Party congress.

production.[8]

For the projects that rank high on the leadership's list, resistance is infeasible. When new plants are constructed, there is significantly less resistance to new technologies. Newly constructed plants embodying obsolete or unworkable technology are largely the responsibility of the R&D sector. The same is true for machines and equipment that are custom-made or produced in small series only.[9] Military industry, with the leading role played by a chief designer of weapon systems and by the customers, also appears to have no resistance to new technology.

In all these cases, the performance of the R&D sector directly influences economic and military outcomes. There have been problems with this performance.

1.2 Performance of R&D sector.

Quantitative expansion has been the main feature of the R&D sector in 1951-85. The number of people employed in R&D increased more than sixfold, and R&D expenditures in current prices grew by a factor of 28. Growth rates of R&D expenditures were in double digits in 1954 - 1964 (see Table 1-1). Employment experienced double-digit growth rates for a shorter period (1956-

[8]This stems from organizational separation of research and development; diversion of resources allocated to testing and experimental production; and inflexibility in the choice of R&D projects. All these are discussed below.

[9]See, e. g., Leont'eva, 1986b, on new aluminum smelters; Polianskii, 1986 on locomotives.

62).

Table 1-1. Growth of R&D sector, annual growth rates, %.

Year	R&D employment	R&D expenditures
1951	6.40*	7.88*
1952	6.40*	7.88*
1953	6.40*	7.88*
1954	7.40*	15.25*
1955	7.40*	15.25*
1956	10.28	15.25*
1957	10.42	18.27*
1958	10.76	18.27*
1959	9.27	16.53
1960	20.59	18.18
1961	14.07	15.38
1962	10.04	15.56
1963	7.09	11.54
1964	5.36	10.34
1965	5.13	7.81
1966	4.42	8.70
1967	3.98	9.33
1968	4.91	9.76
1969	4.62	11.11
1970	3.52	17.00
1971	4.20	11.11
1972	5.04	10.77
1973	5.39	9.03
1974	3.45	5.10
1975	4.71	5.45
1976	1.85	1.72
1977	2.82	3.39
1978	2.52	5.46
1979	4.79	4.66
1980	2.70	10.40
1981	2.24	4.93
1982	-0.05	6.41
1983	-0.09	6.02
1984	0.83	5.30
1985	1.02	2.88

Source: NKh. Note: * - denotes average annual growth rate; no data for individual years available.

Table 1-2. Inputs into R&D as a share of national resources, %.

Year	R&D employment in: Total non-private employment	State sector employment	R&D expenditures in national income utilized, current prices
1950	1.05	1.77	1.35
1953		1.97	
1955		2.05	
1956		2.16	
1957		2.27	
1958		2.45	
1959		2.58	2.48
1960	2.09	2.84	2.73
1961			2.98
1962	2.51	3.24	3.20
1963	2.64	3.36	3.48
1964			3.56
1965	2.74	3.41	3.62
1966	2.79	3.44	3.67
1967	2.83	3.46	3.71
1968	2.90	3.51	3.76
1969	2.97	3.56	3.90
1970	3.02	3.59	4.10
1971	3.09	3.64	4.33
1972	3.18	3.72	4.63
1973	3.29	3.83	4.69
1974	3.34	3.87	4.74
1975	3.44	3.96	4.79
1976	3.24	3.70	4.62
1977	3.28	3.73	4.58
1978	3.31	3.75	4.59
1979	3.43	3.86	4.67
1980	3.49	3.89	4.91
1981	3.53	3.93	4.90
1982	3.50	3.89	4.86
1983	3.47	3.85	4.92
1984	3.48	3.86	4.97
1985	3.50	3.87	5.04

Sources: NKh.

After that, growth of employment kept slowing down to the still high rate of 3-5%% in 1964-1975, 2-3% in 1976-81, and a virtual standstill since then. R&D expenditures, by contrast, went through another spurt of double-digit growth in 1969-1972, then settled at 4-5% level, without recognizable downward trend.

The slowdown in the real growth of R&D expenditures after 1965 must have been more significant than shown by the current-price data in Table 1-1.

The R&D sector was growing much faster than the rest of the economy. As a result, the ever greater share of the nation's resources was allocated to R&D (see Table 1-2). This is an indication of the high priority accorded to the sector by the authorities. The preference for R&D continued even as economic growth was slowing down. The share of resources devoted to R&D has continued to grow through 1980s, reaching 5%. Employment in R&D stabilized in the 1980s at 3.5% of the total employment.

While growth of inputs into R&D has been truly impressive, outputs of this sector grew more modestly.[10] The number of prototypes of new machines, instruments, equipment, etc., created during a year, has been declining since the mid-1960s; and prototypes per R&D employee have been declining since 1960 (see Table 1-3). The number of patented inventions grew over the long run, but declined in the early 1980s.[11] There are fewer inventions

---

[10] Complex issues of measuring R&D inputs, outputs, and productivity will be discussed in Part II below.

[11] For the sake of brevity, "patent" is used to denote inventor's certificate.

per researcher made now than in 1950. There is also evidence of the declining average importance of an invention in the 1960s and

Table 1-3. Productivity in R&D, 1951-85.

Year	Patents granted per thousand: R&D employees	Science workers	(with 2-year lag) R&D employees	(with 2-year lag) Science workers	Prototypes per thousand R&D employees
1950	16.25	71.38			
1955	3.33	14.74	3.84	17.20	
1958	6.05	28.52	7.40	33.77	1.79
1960	5.95	29.61	7.84	36.91	2.29
1962	4.84	20.40	6.07	30.21	1.99
1963					1.95
1964	4.49	18.30	5.06	21.35	1.70
1965	5.26	20.76	5.82	24.38	1.86
1966	5.80	22.32	6.37	25.98	1.85
1967	7.54	27.92	8.19	32.35	1.60
1968	8.33	30.26	9.08	34.95	1.23
1969	10.01	35.43	10.98	40.65	1.25
1970	11.74	40.96	12.71	46.18	1.25
1971	12.95	43.57	13.97	49.47	1.15
1972	13.21	44.32	14.45	50.45	1.15
1973	11.59	39.06	12.83	43.17	1.06
1974	11.41	37.70	12.44	41.76	1.02
1975	8.18	27.06	8.86	29.86	1.03
1976			18.32	60.53	0.98
1977	17.52	54.59	17.50	57.87	0.88
1978			18.34	56.48	0.95
1979			17.84	55.33	0.89
1980	23.52	75.00	25.31	78.39	0.82
1981	18.09	57.40	19.00	60.42	0.72
1982	17.21	53.78	17.58	56.07	0.77
1983	15.88	49.31	15.86	50.31	0.81
1984	18.19	56.02	18.32	57.27	0.80
1985	18.88	57.67	19.24	60.07	0.75

Sources: explained in chapters 4 and 5. * - average annual number in 1976-79.

1970s.[12] All this suggests that R&D productivity may have been declining in the past 35 years. (Productivity of R&D is too complex a concept, and the measures cited above are too partial, to allow us to state confidently at this stage that productivity has been declining).

The Soviets themselves recognize that there is a problem with R&D productivity. "There emerged the tendencies to unjustified "inflation" of the science personnel, decline in its quality, and decline in its efficiency."[13]

If R&D productivity has indeed been declining, this may provide an explanation for some of the technological progress slowdown in the 1970s-early 1980s; it will also impose specific constraints on any current and future attempts to speed up technological progress by giving more resources to the R&D sector.[14]

1.3 Soviet R&D sector in international prospective.

Derek de Sola Price in Little Science, Big Science suggested that science slows itself down as it grows, since more time has to be devoted to exchange of information, rather than to produc-

---

[12]This evidence is cited in Chapter 5.

[13]Bogaev and Savel'ev, 1982, pp. 57-8. See Arakelian and Gubarev on Armenia; Belousov, 1980, p. 197 on patent applications and prototypes of new equipment per science worker, Medvedev, 1986, on sectoral R&D in Bielorussia. Similar statements are quoted in subsequent chapters.

[14]This will be different from, though related to, Bergson's (1983, p. 58) conclusion that low R&D productivity contributed to sluggishness of technological progress.

tion of new knowledge. This means that scientists become less productive over time. In most developed countries the number of patents granted to the country's own nationals declined significantly in 1967-1980. The number of patents per scientist and engineer or per dollar of R&D expenditures declined in all developed countries in this period.[15] It has been argued that this was due to a depletion of the pool of potential inventions.[16]

If R&D productivity has indeed been declining everywhere, for reasons inherent in the logic of development of science and technology, then there is nothing specifically Soviet about this phenomenon. On the contrary, I believe that the explanation of the Soviet R&D slowdown is to be found mostly within the Soviet economy and society.

Let us assume that R&D productivity of the leading scientific powers has in fact been declining (which is not an established fact). This need not influence the measured Soviet R&D productivity trend, for the following reasons.

a. Soviet measures of R&D results are national, not international. "New machine means" new for the USSR (at the best), not the world.[17] The formal requirement is that the invention be

---

[15]Evenson, 1984, pp. 116-117.

[16]Ibid., p. 119. Scherer (1984, p. 124) doubts this interpretation, and suggests that propensity to patent may have changed in this period.

[17]Kontorovich, 1985, p. 286-7.

novel by international standards.[18] However, with only 2% of Soviet inventions being sold abroad, Soviet experts regard the "world novelty" criterion with suspicion.[19] Indeed, there is a glaring discrepancy between the ratio of patents obtained by the Soviet nationals abroad to domestic patents, and similar ratios for developed countries. In 1980, this ratio was 0.028 in the USSR, 1.46 in the US, 2.16 in UK, 0.54 in Japan, 1.48 in France, and 3.43 in Germany.[20] This strongly suggests that most Soviet inventions are not novel by world standards.[21]

b. The level of achievement of Soviet R&D lags behind that of the advanced countries; R&D productivity lags even more. Hence, constraints that apply to the leaders need not bind the followers; even if the world R&D freezes, Soviet R&D may still race ahead until it catches up. And measures of R&D output will reflect catching-up as if it were production of nrw knowledge (see a. above).

In the remainder of this section, we will present the data on the comparative achievement and productivity of Soviet R&D, supporting the statement in b. Such a comparison will also serve as a useful background for the discussion of Soviet R&D.

---

[18] Sbornik, 1983, p.20.

[19] Minin, 1980, p. 82.

[20] Evenson, 1984, pp. 93-5.

[21] Evenson interprets his data in this way; ibid., p. 96. This would exclude the Soviet Union from the world trend, for the latter was analyzed assuming comparability of patent data across countries (ibid., p. 91).

The amount of resources devoted to R&D in the Soviet Union makes it the world leader. Employment in Soviet science and science services in 1979 exceeded total US R&D personnel by 3.2 times (4.26 million vs. 1.333 million), and was even larger than in all OECD countries together! The number of science workers in the Soviet Union was more than twice the number of researchers in the US in 1979, and equal to the number of researchers in the US, UK, Japan, Germany, France, and Italy together in that year.[22] There exist two different versions of the number of scientists and engineers in R&D in the USSR, adjusted to the US definition. According to one version, the number of scientists and engineers in the USSR exceeded that in the US in the late 1960s, and in the late 1970s was higher by 56-63%.[23] Alternatively, the US was overtaken in the early 1960s, and in 1977, had about half the number of Soviet scientists and engineers in R&D.[24]

The share of R&D personnel in total Soviet labor force (almost 3.5%) also was the highest: in the Western countries with the most intensive research efforts, it does not rise above 1.4%, and in most cases is even smaller.[25] The smaller of the two alternative adjustments to the US definition yields a share of

---

[22]Western data are from OECD, 1984, p. 21. Soviet science worker data include people who do only teaching, and are thus exxagerated relative to the Western concept. Because of the numerous differences in definitions, the comparisons are not precise.

[23]Nolting and Feschbach, 1981, p. 44.

[24]Campbell, 1978, p. 38.

[25]OECD, 1984, p. 322. No data on the US.

scientists and engineers in total employment reaching levels of the US in the early 1970s.26

Soviet R&D expenditures exceeded those in the US in the mid-1960s, and were about 50% higher in the late 1970s.[27]

The share of expenditures in GDP was not higher than 2.5% in the developed Western countries over the 1970s. Only in the US in the 1960s and in Belgium in 1970s did this share approach 3%.[28] In the developed capitalist countries, this share does not show any tendency to grow farther, once it reaches 2-2.5%.[29] At the same time, as Table 1-2 shows, the share of Soviet R&D expenditures in Net Material Product (NMP) has grown from 4% to almost 5% over the 1970s. Of course, GNP is larger than NMP, on account of services and depreciation. As a share of GNP, Soviet R&D expenditures in the mid-1960s were equal to those of the US (2.9%), and higher than those of France, Germany, UK, and Japan; in the mid-1970s, the Soviet R&D share of GNP significantly exceeded that of the US (3.7% and 2.2%).[30] Another estimate puts the share of Soviet R&D expenditures, adjusted to the US definition, at 3.5% of GNP in the late 1970s, far above the range of

---

[26]Bergson, 1983, p. 55.

[27]Campbell, 1978, p. 24; 1980, p. 28. Soviet expenditures are adjusted to conform to the US definition, but the comparison is still very tenuous, as explained in the source cited.

[28]OECD, 1984, p. 27; Piekarz, et al., 1984, pp. 244-5.

[29]*Ibid*.

[30]Bergson, 1983, p. 54.

Western experience.[31]

When military and space R&D is excluded, which is a highly conjectural exercise for the Soviet case, both the Soviet and the US shares fall behind those of other developed countries in the 1960s, though the Soviet share is greater than the US share.[32]

Soviet R&D is much less formidable, once we start looking on its outputs. Publishing in specialized outlets is probably the main outcome of research. In 1961, according to a world census of serials, the USSR had slightly more than one-third as many scientific and technical serials as did the US, and slightly less than most of the developed countries.[33] The most comprehensive collection of active scientific and technological serials in the world, the British Library Lending Division, contained 2.5 times more American journals than Soviet ones in 1973.[34] Though the second comparison was derived by methods different from the first one, its result (40% of US serials) is close to the first one.

This means that at a time when the number of Soviet scientists and engineers has caught up with that in the US, their publishing output was significantly smaller. However, since the number of serials is restricted by administrative decisions, and results in publication delays which are longer than those in the

[31]Campbell, 1980, p. 14.

[32]Bergson, 1983, p. 54.

[33]Parrott, 1981, p. 19. The USSR had more scientific serials than the US, but far fewer technical serials.

[34]Frame and Prokrym, 1981, p. 159.

West, it may be a cause of the comparatively low R&D productivity, rather than its indicator.[35]

Citations in foreign journals can serve as a proxy for quality of published output. A Soviet study of citations for the mid-1960s found that the USSR, while producing 20% of journal articles, was getting only 3-4%, and never more than 5.5%, of world citations.[36] By contrast, the shares of English- and German-language citations is close to the shares of respective publications. A study of scientific citations across the nations found that the Soviet works were the least frequently cited, and depend relatively more on foreign-generated knowledge, than those of the US, UK, FRG, France, Japan, Canada, and the group of all other countries in 1973-4.[37]

In 1976, the ratio of USSR citations of US publications to US citations of USSR publications (the reciprocity ratio) was close to 1 in mathematics. The two countries exchanged equivalent amounts of knowledge in this field. The ratio was 1.7-1.8 for physics and earth and space sciences, 2.5 for chemistry, 2.9 for biology, and 3 for engineering and technology, indicating different lags of the respective Soviet fields behind the American ones.[38] The overall US/USSR reciprocity ratio (2.37) is significantly larger than corresponding ratios for UK (1.14),

---

[35]Parrott, 1981, pp. 16-22.

[36]Nalimov and Mul'chenko, 1969, pp. 139-48.

[37]Burke and price, 1981, p. 371.

[38]Kruse-Vaucienne and Logsdon, 1979, p. 4.

West Germany (1.7), France (1.8), Japan (1.64), and Canada (1.19), indicating indirectly the Soviet lag behind these countries.[39]

A very low number of citations of Soviet papers was also established in the study of the world's most highly cited papers.[40] This holds true for all fields, and was confirmed by a number of other studies.[41]

The Soviet share of world scientific and technical publications is smaller than the Soviet share of world R&D resources; and the Soviet share of citations is smaller than share of publications. This means that an average Soviet scientist and engineer produces fewer publications than his Western colleagues; and each such publication gets cited less often than a Western one. The number of scientists per one publication cited in the US is below 1 in English-speaking countries, below 2 in Germany and France, 4.76 in Japan, and 53 (!) in the Soviet Union.[42]

It must be stressed that the relative lack of citations cannot be wholly attributed to the lower quality of work; it partly reflects the relative unfamiliarity in the West with Soviet science.[43] Also, the style of Soviet publications is

---

[39]Kruse-Vaucienne and Logsdon, 1979, pp. 5-6.

[40]Narin et al., 1983, p. 309.

[41]Reviewed in Narin et al., 1983, p. 310.

[42]Kruse-Vaucienne and Logsdon, 1979, pp. 5-6.

[43]Ibid., pp. 310-1; see also Kresin, pp. 17-19, and Azbel, 1984. Lack of knowledge of Soviet science stems from two main sources: travel to and from Soviet Union is severely restricted,

different from those in the West: they are too concise because of the editorial policies that emphasize saving paper.[44] According to another observer, Soviet scientific articles are written with less care.[45] This makes Soviet articles harder to read and understand, whatever their intrinsic scientific value. A rare Soviet discussion which concedes lags in some disciplines, attributes the phenomenon in general to the barriers for dissemination of information: lack of informal, personal contacts between Soviet and Western scholars; delays in getting foreign publications, and inability to get some of them; lack of knowledge of foreign languages in the Soviet scientific community; long delays in publishing completed work; the inability of foreign scientists to read Russian, and the fact that Soviet work is not translated into English domestically; bad organization of libraries, especially concerning foreign publications; and lack of specialized, computerized information centers.[46]

The Soviet lag in sciences is also apparent in the low number of Nobel prizes won by the Soviet scientists (4), all of them in physics.[47]

---

and publishing in Western journals requires a lengthy permission process.

[44]Kresin, p. 18; Nalimov and Mul'chenko, 1969, p. 161, Parrott, 1981, p. 22.

[45]Azbel', 1984, p. 124.

[46]Nalimov and Mul'chenko, 1969, pp. 161-9. More on this subject, and more recent information, is in Parrott's (1981) interesting work.

[47]Kruse-Vaucienne and Logsdon, 1979, p. 4.

The Soviet Union has become the world leader in the number of patents granted to its own nationals since 1974. As argued above, the weight of a Soviet patent, or its novelty, is less than that of developed Western countries. Still, the number of patents granted per science worker in the USSR in 1980 is significantly lower than the number of patents per scientist and engineer in France and Japan, somewhat lower than in Germany, and commensurate with that in the US and UK.[48]

On a more specific level, the R&D effort in the Soviet machine tools industry was found to be proportionately much larger than that in the same sector in Britain, though the latter was more advanced than the former.[49] GKNT compared Soviet research establishments to similar ones in the developed countries and found that the Soviet organizations "have more staff than necessary with rational level of equipment."[50]

There is a cumulation of the Soviet lag behind the West as one moves from the initial stages of R&D to the later ones. There is no lag in mathematics. The lag appears in the natural sciences, and probably grows as one goes from theoretical to experimental fields. The lag is still greater in technology and engineering (as attested by reciprocity ratios for citations in

---

[48]See Table 1-3, columns 3 and 4, and Evenson, 1984, p. 113. Scientists and engineers (input measure for Western countries) is broader than science workers, so that Soviet productivity is upward biased in this comparison.

[49]Berry, 1982, pp. 99-100; Berry and Cooper, 1977.

[50]Pokrovskii, 1983, p. 80.

different fields). Then at the level of development it must be getting even worse, and still worse when put into series production, as reflected by low competitiveness of manufactured goods in the world markets. All this adds up to produce the lag of the Soviet technological level behind that of the West.[51]

The lag in comparative performance becomes all the more striking if one keeps in mind that much of what the Soviet R&D sector is doing is not creating new technology, but rather imitating existing Western technology.[52] Imitation is a good strategy for laggards who are trying to catch up, because it is cheaper. Soviet R&D resources are commensurate with those of the leaders, while performance is that of a laggard. Their imitation is more expensive than creation of original new technology. What is the explanation for this paradox? An imitation strategy, pursued inflexibly, may freeze a country into a permanent lag; if resources are deployed so as to imitate, one would be getting belated copies of what already exists elsewhere. Alternatively, systemic features of the economy and society may make R&D resources unproductive, perpetuating the status of a laggard, thus making imitation "the best" strategy forever.[53] My view of the

---

[51]See Amann, et al., 1977.

[52]For Western statements, see Sutton, 1968-73, Siemaszko, 1982, pp. 249-50. Soviet references are cited in footnote 3 in section 1.1 above.

[53]See Gustafson, 1980, for a lucid analysis of some of the organizational characteristics of Soviet R&D that make it less productive than its American counterpart. For import of knowledge and its impact, see Hanson, 1982, and Gustafson, 1981.

function played by imitation in Soviet R&D will be developed in Chapter 16 of this report.

1.4 The objectives of this study.

This project concerns changes in R&D productiivty in the past 35 years, their causes, and prospects for the future. I will analyze some quantitative indicators of R&D productivity, such as patents or prototypes of new machine per scientist and engineer. These indicators are valuable, for they give some measure of processes in the R&D sector. However, these indicators are also partial; they do not reflect the integral productivity of the sector. Therefore, we will also analyze the processes in the R&D sector which are not measured or even measurable, but which influence productivity, broadly understood.

Chapter 2. How Advances in Knowledge Are Produced.

Research and development has been described above (in 1.2 and 1.3) using economic terms: input, output, productivity. These terms have originally been defined for production of goods and services. Their applicability to R&D is discussed in sections 2.1 - 2.3. Section 2.4 discusses the problems of measuring R&D inputs, outputs, and productivity.

2.1 R&D: inputs and outputs.

The output of R&D is new knowledge; its inputs are labor, capital, and materials. Labor includes scientists, engineers, technicians, workers in experimental and pilot production facilities, and administrative and auxiliary personnel of R&D organizations. Capital includes equipment, instruments, and buildings that house them. Material inputs include electricity, materials for experimental and pilot production work, etc. Like industry or agriculture, R&D includes different activities, requiring different quantities of labor and capital. Theoretical work may not require any capital or materials at all, except for paper and pencil. Experimental research and development require equipment.[54] Capital/labor ratios vary greatly in particular fields, but the general trend seems to be towards more capital intensive

[54] Gustafson (1980, p. 33) attributes the relative success of Soviet field work in oceanography, geology, and biology to superior logistical support.

R&D technologies. Apparently, there exist indivisibilities: certain kinds of research cannot be conducted without certain minimal amount of equipment. At the same time, within certain limits, hard work and ingenuity can substitute for missing or inadequate capital.

All these characteristics are common for R&D with production processes elsewhere in the economy. The main difference is the role of individual characteristics of labor. Economics regards workers to be homogenous and interchangeable within broad classes defined by education, demographics, and experience. This view is acceptable for some auxliary activities in R&D (drafting, manual work in experimental and pilot production facilities). It is not acceptable for the main R&D activities. The main characteristic of a scientist or an engineer important in R&D is creativity. Creativity is highly unevenly distributed among individuals, is not observable and correlates only weakly, if at all, with observable characteristics such as age/sex, education, and experience. It also appears that creativity cannot be substituted for by any quantity of labor or equipment. A million blockheads will not produce the result that one genius can. A blockhead with the best equip-ment will not get the results that a genius will get with the most primitive equipment. Creativity is the most important input into R&D.

2.2 Institutionalized domestic R&D and other sources of new knowledge.

Knowledge is an important input into creation of knowledge. New results in one area of research may give rise to other research directions, new products and processes. There are two sources of new knowledge external to the domestic R&D establishment: independent inventors, and imports.

The entire output of steel in a nation is produced in specialized plants or shops built expressly for that purpose. The same is true for most other products produced for sale (production for their own consumption by firms and households is a different story). R&D results, by contrast, can spring up everywhere, not necessarily in the organized R&D sector. In fact, a surprisingly large proportion of the most significant inventions is attributed to individuals working outside the organized R&D.[55] These inventors may be people working in their spare time in pursuit of their interest, or production engineers solving a problem encountered in their everyday work. This unorganized R&D activity underscores the comparatively low importance of equipment for some activities, and the crucial importance of personal characteristics of human actors (creativity). It also makes it impossible to pin down accurately the number of people engaged in R&D.

An automobile can be made out of domestically produced or imported steel. Similarly, a new design or research direction

[55] Jewkes et al., .

can be based on a domestic or imported idea. However, if imported products can be easily identified and differentiated from the domestic ones, movement of knowledge cannot be similarly registered, except for cases when it is embodied in goods or sold under a license. While it is known how much foreign grain, chemicals, and equipment are used in the Soviet economy, similar statements cannot be made about the procurement of knowledge from abroad. Researchers and designers import knowledge in an unorganized way, when they decide to adapt or develop an idea encountered in reading professional publications, listenting to papers at international conferences, or looking at a foreign product. There is also an institutionalized channel for importing new knowledge in an unobservable way: espionage.[56] Above, we have already mentioned the extraordinary importance of imitating foreign technology for the USSR. Imitation represents for the most part import of knowledge in the forms that are hard to pin down.

Any analysis of productivity of R&D sector has to account for these important sources of inputs.

2.3 Relation between inputs and outputs.

In the production of goods and services, the recipe for converting given quantities of inputs into output is known with certainty. No such recipe is available for R&D, which, by definition, is engaged in finding things that have not been previously known. It is a situation of dimly perceived risk; individuals

[56] See Hanson, 1987.

disagree on their assessments of risk.[57] "Humans engaged in inventive efforts simply do not, and in the nature of the case cannot, comprehend the set of alternatives that they face. The set is fundamentally vague."[58]

Many research strategies (recipes for converting inputs into outputs) are possible, but some of them will prove to be fruitless; it is impossible to tell beforehand which ones they are. (Creativity may be considered the ability to select the research strategy with high probability of success, as well as the ability to proceed quickly once it is selected.) There is no functional relation between inputs and output for an R&D project. Spending more money or hiring more researchers does not guarantee any useful result. If deployed wisely (running parallel projects, exploring alternative strategies), additional inputs would increase the probability of producing a result.

The degree of uncertainty declines, and the role of inputs rises, as one goes from fundamental research to development. Witness the usual story of an invention made by an individual or a small firm, and developed by a large firm because of the resource requirements.[59]

We are analyzing the national R&D establishment, or large sections of this establishment, including hundreds of thousands

---

[57]Nelson, 1981, p. 105.

[58]Nelson, 1981a, p. 1046.

[59]See, e. g., Williamson, 1975, p. 192.

of projects.[60] These projects are independent one another. Adding inputs to a large number of independent projects increases the probability of success in each of them; some would actually produce useful results. Therefore, on the aggregate level, there is a functional relation between inputs into R&D and its results.

The productivity of R&D resources depends on which area of nature or technology is subjected to study. In some areas (e. g., high-technology sectors) R&D brings a substantial increase in knowledge; in other areas (some services and production of many low-technology goods) it brings a small or no increase. "... R&D and fast productivity growth naturally occur together in firms and industries for which there are technological opportunities, often in science-based industries. In other words, it is not simply the R&D that spurs productivity, it is the R&D taking advantage of technological (combined with economic) opportunities. Without them, R&D spending would have little economic payoff. It appears that most industrialized countries spend the most for R&D in the same industries ... In a rough sense, then, industrial R&D spending both reflects technological-economic possibilities and realizes some of them ..."[61]

---

[60]There are 150 thousand research projects, and 300 thousand experimental and design projects going on (or being completed?) annually. Apparently, this number includes only significant projects that are entered in the national registry. Nekhoroshev, 1979, p. 7.

[61]Piekarz, et al., 1984, p. 239.

2.4 Measurement of inputs and outputs.

Measures of inputs into R&D - expenditures and total employment, and number of scientists and engineers - are widely accepted and non-controversial. This does not mean that these measures are necessarily meaningful. Employment measures count bodies and omit the main input - creativity. Inputs in R&D activities outside R&D establishments are not covered. Problems of coverage specific to the Soviet data on inputs will be discussed in the following chapters.

Measures of R&D output are much more debatable and problematic than inputs. Output of R&D - new knowledge - cannot be measured. Only its physical embodiment - reports, drawings, prototypes, publications, patents - can be measured (see Table 2-1).

Each of these measures reflects only one particular segment of R&D output. Some of these measures overlap: project reports, publications, patents, and prototypes may embody one and the same result in different forms. On the other hand, some aspects of output probably are not covered by any measurable proxy. It does not seem possible to derive an aggregate measure of output by weighting the available partial measures. So one has to deal with multiple partial indicators of output.

Some of the observable results of R&D may be devoid of new information. If the share of trivial results changes over time, this will distort the measure of changes in R&D output and productivity. Therefore, some indicators of quality, novelty or

significance of R&D results is necessary. The usual indicators of quality for publications are citation counts; for domestic patents, share patented abroad. Expert evaluations of particular aspects of quality are also useful.

Table 2-1. Structure of R&D output by type of product in 1971, shares, %.

End result of a project	Basic & mission-oriented research	Applied research	Design & testing
Technical & normative documents	37.6	76.0	45.6
Project & design documents	0.4	0.9	18.8
Laboratory & experimental prototype, new product or substance	1.2	2.5	16.4
New production process, regime, schedule	0.7	5.6	16.4
Publications & dissertations	12.1	3.6	1.1
Other positive results (recommendations, methods, etc.)	46.7	11.0	1.5
Negative result or cancellation	1.3	0.4	0.2

Source: Kanygin, 1974, p. 228.

The two measures used in this report, patents and equipment prototypes, do not represent all R&D output. Patents represent the results of applied research and development across all disciplines, but unevenly, because propensity to patent varies by field.[62] The output of fundamental research is represented only indirectly, to the degree that it allows scientists to make patentable inventions. Prototypes of new equipment represent applied research and development in machinebuilding.

Taken together, these two measures cover mostly output in applied research and development in engineering and technology,

---

[62] Yankovsky, 1982, shows how propensity to patent varies across Academy institutes in different disciplines.

and related scientific disciplines. This includes the main avenue of technological progress in the modern economy and defense: creation of new machines and equipment.[63] High technology fields such as electronics, computers, and communications equipment are covered. Chemistry and chemical technology may have a weaker representation, and biology, a still weaker one.

Publication data are much broader than patents and prototypes, and may correct for the biases of the latter against fundamental research and against chemistry and biology, but they have their own numerous shortcomings in the Soviet case, discussed in Chapter 6 below.

Output measures used in this study are narrower than input measures. The latter usually relate to all R&D, including the parts that produce no or few patents and prototypes. On the other hand, prototypes and patents are quite frequently produced by people outside the formal R&D establishments, and on this account inputs measures are incomplete. It will be shown that the segments of R&D expenditures and employment relevant to our output measures were growing faster than the total inputs, hence our measures of R&D productivity change (such as in Table 1-3) are upwardly biased.

The partial nature of the available output measures makes it necessary to go beyond the quantitative measures of productivity and take a broader look at processes in the R&D sector.

---

[63]New machines serve as a conduit for technological progress into all sectors of economy. See Kontorovich, 1985, p. 282.

Chapter 3. Institutional Background.

The purpose of this chapter is to describe the organizational framework within which Soviet R&D operates. Coordination and incentives provided by organizations determine both the uses to which R&D inputs are put and the efficiency of their utilization. The organization of the sector has been in flux during the period investigated in this report. Giving a full account for the structure at any fixed moment would therefore be misleading. We try to reflect the evolution of particular elements over time, and supply a chronology of changes in the last section of this Chapter.

3.1 Boundaries of the sector.

Soviet statistics defines a sector of the economy called "science and science services". This is the best approximation of organized R&D activities available in Soviet statistics. We will use the terms "science and science services" and "R&D sector" interchangeably. Unlike ferrous metallurgy or shipbuilding, R&D sector is not administratively unified; it includes the establishments subordinate to a large number of ministries and committees. By statistical convention, R&D organizations are considered non-productive, even when they are subordinate to ministries in the production sphere.

There are two criteria in defining the sector of science and science services: function and organizational independence

(neither one is applied consistently. The sector includes organizations that "systematically conduct research according to a properly approved plan of R&D",[1] and are organizationally indepdendent. These include:

- research organizations ("science" subsector of "science and science services" sector);
- design and project-making organizations, except for those in construction and forestry sectors;
- experimental and pilot production plants that serve solely the needs of R&D;
- hydrometeorological service;
- science service organizations.[2]

Defined in such a way, R&D sector includes some establishments that should not be included. Archives, museums, and libraries conducting research are included among research organizations, although research does not appear to be their primary function. The same is true for computer centers, national parks and preserves, and zoos and botanical gardens. Moreover, there is no uniformity in including science libraries, computer centers, some units of statistical organs, scientific publishing houses, some units of project-design organizations, etc.[3] While these are of minor importance quantitatively, the hydrometeorolo-

---

[1]Serov, 1972, p. 47.

[2]For more detail, see Appendix A.1.

[3]Serov, 1972, p. 47.

gical service is a large subsector, responsible for weather forecasting and information, environmental pollution monitoring, and other non-R&D functions. Finally, the science services subsector includes organizations that conduct such routine, non-R&D functions as surveys of stock of fish, whales, and sea animals; laboratories for checking measurement instruments and for testing construction materials; and bureaus for dissemination of technical information.

The criterion of independence requires that R&D units of production and teaching institutions be excluded. Many design, testing, and pilot production units subordinate to industrial enterprises indeed are not included in the R&D sector (which is a major omission). However, the most important R&D units of production enterprises are classified to be R&D organizations by TsSU, once their respective ministries include them in a special list that has to be approved by GKNT.[4] This allows enterprises to use centralized sources of financing for these units, in addition to their own funds.[5]

Institutions of higher learning are classified as part of the education sector.[6] At the same time, since the mid-1960s, institutions of higher learning have been listed as a particular

---

[4]Bliakhman, 1979, p. 62. This includes such small and obscure units as the central laboratory for technological research and adjustment (naladka) of Briansk automobile plant (Natapov, 1986).

[5]Gvishiani, 1973, p. 231.

[6]Gosplan 1974, p. 765.

group of R&D organizations in statistical yearbooks. Their treatment in *expenditures and employment statistics* will be described below.

3.2 Three systems of R&D.

Research and development institutions fall into three large classes: academic, sectoral, and teaching.[7] These classes are administratively separate and are intended to perform different functions: fundamental research; applied research and development in particular sectors of the economy; and teaching along with research (respectively).

3.2.1 Academies.

The Academy of Sciences of the USSR (henceforth, Union Academy) is subordinated directly to the Council of Ministers, and plays the role of a "ministry of science", alongside with ministries of coal, automobiles, etc. Institutions of Union Academy are located in the Russian republic, which does not have a republican academy. Academies of Sciences of the other fourteen Union republics play analogous roles on the local level.

Along with their primary task, fundamental research, academies are obligated to prepare recommendations for implementation of their results, and to take part in this implementation. In practice, this means that they have to perform some applied

---

[7]This section is largely based on Beliaev and Pyshkova, 1979.

research, development, and in some cases, even small-scale production.[8]

In 1961 and 1963, institutions of the Union Academy that specialized in technical sciences were transferred to the respective sectors of the economy. The transfer involved half of all the Academy institutions (a total of 97, including 51 institute and 7 branches of institutes) and one third of its employees (20,000 persons). These were the institutes which conducted much applied research on contract for particular sectors. The purpose of the transfer was to strengthen sectoral science, and move practitioners of R&D closer to the users. Competition for funds between the Division of Technical Sciences and the rest of the Academy may also have played a role.[9]

The Academy is ruled by the Presidium, which has 4 sections, overseeing 16 divisions along the lines of scientific disciplines, plus a multidisciplinary Siberian division (as of 1977). Sections were created in the late 1960s to cope with the growing number of divisions, reflecting increased specialization of research. R&D establishments are subordinated either to their particular divisions, or directly to the Presidium, or to regional centers and branches, or disciplinary centers, most of which were developed over the 1960s and 1970s. Centers are subordinated directly to the Presidium, while scientific guidance is conducted by the divisions responsible for a particular discipline.

---

[8]See, e. g., Ibragimova, 1973, pp. 44-45.

[9]Rassokhin, 1985, p. 239-240.

Management is very centralized, with the president, vice presidents, and the chief scientific secretary holding an inordinate amount of power. For example, academy members are given foreign currency allotments for subscription to foreign scientific literature. When price increases abroad force an increase in the individual allotment, this has to be approved by the president himself.[10] Divisions have comparatively little power.

Most institutions of the Academy have traditionally been located in Moscow and Leningrad. In the last thirty years, territorial dispersion of the Academy has been vigorously promoted. Siberian division, the Urals and Far Eastern Centers, and other centers and branches have been founded and expanded. Regional centers are to devote special attention to the problems of their particular regions, and also coordinate R&D conducted by teaching and sectoral institutions located in the region. Inter departmental councils are created for this purpose.

Most republican Academies were formed in the 1940s and 1950s. Republican academies similarly are supposed to coordinate all research in their republics. Recently, the Ukrainian academy established six regional centers, patterned on similar centers of the Union Academy.[11]

Sectoral academies are a cross between the academy system and sectoral science. They are intended to carry out fundamental research, but are subordinated to their particular sectoral mini-

---

[10]Ginzburg, 1986, p. 43.

[11]Rudich, 1985.

stries. The two significant ones are the agricultural academy which conducts R&D in agriculture, forestry, and water management, and the academy of medicine. The smaller ones are the academies of pedagogy, arts (a very small academy) and municipal services. The latter, naturally, engages only in applied research and development.

3.2.2 Sectoral science.

Sectoral science is performed in the establishments subordinate to ministries running particular sectors of the economy (e. g., coal; petroleum; automobiles), or to state committees responsible for certain functions throughout the economy (e. g., Committee on Standards). In 1957-64, when the economy was managed along territorial lines, many sectoral institutions were subordinated to the regional economic councils.

Ministries determine the direction of R&D in the sector, approve plans of their R&D establishments, and handle their financing and supply. Within a ministry, allocation of resources for R&D and management of R&D institutions is split among several departments. Research institutes and design bureaus are usually subordinated to the main administrations for particular subsectors. Some research institutes may be subordinated to the main technical administration of a ministry. General direction for R&D in the ministry is developed in some cases by technical administration, and in other cases, by planning and economic and/or construction administration.

R&D units of production enterprises are directed by the management of these enterprises and by corresponding subsectoral main administrations (glavks).[12] It is not clear how much central supervision is accorded to the units classified as belonging to R&D sector.

3.2.3 Teaching institutions.

In 1986, there were 894 higher learning institutions, subordinate to 74 different Union or republican ministries and committees. The largest single group is subordinate to the Ministry of Higher Education of the USSR (directly or through corresponding republican ministries). Some higher learning institutions are subordinate to sectoral ministries (medical, agricultural, transport, and some others). Thirty ministries have only one or two higher learning institutions under their direction.[13]

Since the primary mission of these organizations is to teach, their research activities habe been getting significantly less attention: they have been more loosely planned, and in some cases not planned at all; and have been getting much smaller allocations for equipment.

There are constant attempts to change this. Every few years, there is a new decree adopted by the Council of Ministers

---

[12] Marek and Semenov, 1985, p. 9-11. There is no legal act or norm defining their status (Rassokhin, 1985, p. 109-10).

[13] Gvishiani, 1973, p. 93; "Osnovnye napravleniia perestroiki ...", 1986, p. 1.

(CM) and Central Committee (CC) on increasing the involvement of teaching institutions in R&D. Thus, in 1964 the aim of integrating teaching institutions into the national planning system was announced.[14] A decree in 1978 allowed leading teaching institutions to plan, finance, supply and organize R&D similarly to research organizations.[15]

In 1980, the Ministry of Higher Education of the Russian republic established a self-financing scientific association (R&D _glavk_) to coordinate, plan, finance, and supply research in the most important teaching institutions. It performs 678 million rubles of research (all research of the Ministry). The aim is to concentrate research on a few main directions, cutting down on insignificant topics and duplication. Organizational forms characteristic for the other two systems of R&D are being introduced for the first time in teaching institutions: goal-oriented programs, orders for research (_zakaz-nariady_), incentive funds for payment of bonuses. (These organizational innovations are described in more detail below in this Chapter.) Reportedly, there has been a switch from financing institutions to financing projects.[16] Yet it is argued that self-financing R&D association changed little in the actual operation of subordinate organiza-

---

[14]CC and CM decree of February 20, 1964 "On further development of R&D at teaching institutions".

[15]CC & CM decree "On increasing the effectiveness of R&D in institutions of higher learning" of April 6, 1978.

[16]Obraztsov, 1986, pp. 7-11.

tions.[17]

3.3 People.

3.3.1 Definitions of employment.

Two broad measures of labor input in R&D are compiled by Soviet statistics: R&D employment and science workers.[18] R&D employment includes everybody employed by organizations classified as part of the R&D sector (see 3.1 above). This would include all personnel of research and development organizations: scientists, designers, engineers, technicians, administrators, draftspersons, manual workers, and janitors. The drawbacks and advantages of this measure are those of the definition of the R&D sector: it includes employees of non-R&D institutions, and excludes most people doing R&D at the teaching institutions and at some units of industrial enterprises.

Science workers is another category, which is frequently used in this report because of relatively greater availability of data. It includes researchers (scientists and engineers) both in R&D and in non-R&D organizations; teachers at higher learning institutions; and all persons with scientific rank or degree irrespective of their work. The category of science workers exaggerates the number of researchers by including teaching personnel, many of whom do no or little research, and also by including

[17] Mikhailov, 1986.

[18] See Appendix A.2 for details and sources.

persons with scientific degree and rank who are administrators, officials, etc.

3.3.2. Ranks and degrees.

There are two scientific degrees: candidate of science, roughly equivalent to Ph.D., and doctor of science, awarded to scholars at the level of full professor. Both degrees require completion of a dissertation that has to be approved by a local scientific council, and then pass the review at the All-Union Attestation Commission (VAK). Employees of research establishments write their dissertations on the job, on the topics on which they are working.

There are also academic ranks: assistant, docent, professor at teaching institutions, and junior and senior science worker (MNS and SNS) in research institutions. The ranks of assistant and MNS are awarded by decision of the scientific council at one's place of work, while higher ranks have to be approved by VAK.[19] The highest ranks are those of corresponding and full member of an academy, bestowed by vote of the meeting of the members of an academy.

For those employed in "science" subsector, salary is raised with degree; for those in teaching institutions, only with rank.[20] The raises are quite substantial. Defending a dissertation has been the main avenue for getting higher pay in an R&D

[19] Lakhtin, 1983, p. 75.

[20] *Ibid.* p. 77.

organization. Academy members are very highly paid and enjoy a number of privi-leges that put them in the highest strata of the society. The ranks of SNS and especially MNS are not particularly meaningful in research organizations; the number of science workers with these ranks has been falling since 1970.

Researchers with scientific degrees are unevenly distributed across the three systems of R&D. In the Union Academy, doctors of science frequently have the rank of senior science worker, while in sectoral institutes, people with this rank may have no scientific degree at all.[21]

3.4 R&D organizations.

Each of the three systems of R&D consists of thousands of establishments of different size, name and function. It is these that are ultimately responsible for the production of new knowledge.

3.4.1 Types of establishments.

Institutes (NII in the sectoral science) are the main type of research establishment in the "science" branch of R&D, employing most researchers.[22] Data for the Academy of sciences (Table 3-1) and early data for science subsector of R&D (Table 3-2) demonstrate this. In 1977, there were approximately 2000 insti-

[21] Sominskii and Torf, 1972, p. 46.

[22] Bliakhman, 1979, p. 62.

tutes.[23]

Table 3-1. Distribution of institutions and science workers in the Academies by type of establishment, end of 1973.

	Institutions			Science workers		
	Union	Republic	Total	Union	Republic	Total
Total	100.00	100.00	100.00	100.00	100.00	100.00
Institute	72.65	72.38	72.48	89.77	89.26	89.50
Branch of NII	5.31	2.30	3.46	3.72	1.43	2.52
Research labs	1.22	0.77	0.94	0.43	0.33	0.37
Research & experim. stations	1.22	1.79	1.57	0.08	0.13	0.11
Observato-ries	1.63	1.53	1.57	0.81	0.66	0.73
Botanical gardens	1.63	4.09	3.14	0.86	1.27	1.08
Museums	0.41	2.30	1.57	0.03	0.49	0.27
Other	15.92	14.83	15.25	4.30	5.95	5.17

Source: NKh-73, p. 180.

Institutes are large hierarchical organizations with hundreds of employees. In the early 1970s, in the academies of sciences scientists and engineers alone numbered, on average, 150 persons per institute (see Table 3-3); the total number of employed is likely to be twice as large on account of support personnel.

Other types of research organizations include territorially separate divisions of the institutes, independent laboratories,[24]

[23]Bliakhman, 1979, p. 61.

[24]Laboratory also denotes a basic administrative unit of an institute, or a unit at a production enterprise.

observatories, and scientific-experimental stations, numbering more that 3,000 in 1977.[25] As Tables 3-1 and 3-2 show, these establishments are small, and thus employ only a small proportion of researchers.

Table 3-2. Science institutions by type, end of 1955.

	Number	Science workers (thous.)	Science workers per institution	Share of institutions, %	Share of science workers %
Total	2797	97.80	34.97	100.00	100.00
NII	1064	73.50	69.08	38.04	75.15
Branches & divisions of NII	146	3.80	26.03	5.22	3.89
Science stations	574	6.20	10.80	20.52	6.34
Support points, experimental fields, & experimental bases	184	0.60	3.26	6.58	0.61
Laboratories	142	2.60	18.31	5.08	2.66
Observatories	38	0.70	18.42	1.36	0.72
Environmental protection	74	0.70	9.46	2.65	0.72
Commissions, sections, councils, committees, sectors & branches of the academies	60	2.10	35.00	2.15	2.15
Museums	392	3.50	8.93	14.02	3.58
Libraries	61	2.00	32.79	2.18	2.04
Others	62	2.10	33.87	2.22	2.15

Source: TsSU, 1956, p. 245.

Data on insitutions in subsectors of R&D other than "science" are scarce. Design organizations are divided into project-making, design, and technological ones. These terms apply to design of buildings and structures, industrial products, and

[25]Bliakhman, 1979, p. 61.

industrial processes, respectively.[26] The main type of organization is a project-making institute of design bureau, similar in size and structure to NII. In 1965, there were 2393 such organizations, including those in hydrometeorological service and

Table 3-3. Average number of science workers per institution of Union and republican Academies, end of 1973.

	Union	Republic	Total
Total	157.88	108.63	127.60
NII	195.07	133.98	157.56
Branches & divisions of NII	110.69	67.33	92.95
Research laboratories	55.00	46.33	50.67
Research & experimental stations	10.67	7.86	8.70
Observatories	78.25	46.83	59.40
Botanical gardens & dendraria	83.25	33.75	43.65
Museums	12.00	23.33	22.20
Other	42.69	43.60	43.24

Source: NKh-73, p. 180.

other non-R&D fields.[27] In 1977, there were 3000 project-design organizations.[28]

Independent pilot production plants and units (<u>proizvodstvo</u>) constitute still another category of R&D institutions. There were 3,000 testing and experimental bases of R&D and teaching organization in 1977; independent units accounted for

[26]The names may be misleading: some KBs are in fact NIIs, and vice versa (Zavlin and Iudelevich, 1985, p. 5).

[27]NKh-65, p. 67.

[28]Bliakhman, 1979, p. 61.

60% of all employees of such organizations.[29]

Though there have always been some R&D organizations that were of mixed nature, the general principle was to create "pure" organizations. Research institutes carry out research. Development of their research findings is done at specialized and independent design bureaus. Pilot production and testing is conducted in specialized plants. And actual production is carried out at a third place: production enterprise.[30] For example, in machinebuilding, design-technological institutes (PTI), dealing with the complete R&D cycle, are rare.[31] Technological institutes in the ministry of construction materials are staffed by technologists who are developing the processes, but lack designers to develop the machinery necessary to carry out these processes.[32]

Since the 1970s, this trend has been counteracted, and possibly reversed, by the creation of organizations that combine different stages of the R&D cycle, and sometimes also production. These include NPOs (science-production associations), which merge production firms with one or several types of R&D organizations, and some other types of conglomerates, in sectoral R&D.[33]

---

[29] Ibid.

[30] Golland, 1981, p. 84.

[31] Efimov, et al., 1985, p. 50.

[32] Vorob'ev, 1986.

[33] Bekleshov, 1986, pp. 38-9. For more detailed analysis, see 15.3.1 below.

The largest number of the smallest R&D units is within production enterprises. Most of these are not considered R&D organizations, often with justification.

Table 3-4. Number of R&D units at 44,111 industrial enterprises (beginning of 1973).

Total	72447	
Laboratories	43141	
including:		
Central (plant, factory)		20415
Shop		15013
At the departments of plant administration		7713
Design units	24466	
including:		
Departments of chief designer		3045
Project-design, technological, design bureaus, departments		7242
Design bureaus, sectors, groups at:		
departments of plant administration		10629
shops		2607
Testing and experimental units	4840	
including:		
At the shops		1806
At the divisions (uchastki)		2175
At the workshops (masterskie)		370
Other		489

Source: Kostin, 1974, p.83.

In industry, there are 87,000 laboratories, design and experimental units, with 1.7 million employees.[34] Table 3-4 provides a breakdown of such units by type for an earlier date. In 1973, there were on average 1.6 such units per enterprise, employing on average 19 persons, 9 of whom were scientists, engineers, or technicians.[35]

The functions of plant laboratories at machinebuilding

[34] Kushlin, 1986, p. 216.

[35] Kostin, 1974, p. 83.

plants are given as follows:

i. testing of machines and their parts (usually within the department of chief designer or within the experimental shops subordinate to the chief designer);

ii. checking, repair, presentation to the State Committee on Standards and Measurements of measurement instruments (apparently, used at the plant);

iii. testing, research, and technological laboratories combined in the central plant laboratory (TsZL). Their functions may include: quality control of raw materials, parts, and other inputs arriving at the plant, and circulating within the plant; quality control of output, research into the causes of faults in output; inspection of technological processes and development of measures for their stabilization; cooperation with design and technological services in improving the parameters of output and production processes; research; implementation of outside research results; manufacturing of equipment for experiments and research; checking adherence to technological rules and instructions in production.[36]

Functions in ii. and some of the functions in iii. do not represent R&D activity.

There were more than 850 higher learning institutions in 1977, excluding teachers' colleges.[37] The basic organizational unit of a teaching institution is a department (kafedra), which

---

[36]Golosovskii, 1969, pp. 105-6.

[37]Bliakhman, 1979, p. 61.

conducts both teaching and research. There are also specialized research units: NII and laboratories. They are subordinated, as a rule, to the research department or sector of the institution.[38] There are currently 1,300 laboratories and bureaus, and 50 institutes.[39]

Some of these laboratories and NII have existed for a long time, but the major push for their creation came relatively recently. Creation of "problem laboratories" of the leading teaching institutions was decreed in 1956, and they began to crop up in the late 1950s-early 1960s. A problem laboratory conducts research on the problem approved for it, and helps the corresponding organizations in development and implementation of their results. Sectoral laboratories conduct research on creating new materials and prototypes of new machines, and make recommendations for and oversees their implementation. Some sectoral laboratories are financed by their respective sectors. Laboratories may be departmental, interdepartmental, and inter-school. A rather rare example of research cooperation of different institutions is the North-Caucasus universities' research center, created in 1969.

The status of some of these units is much less firm than of those in the other two systems. Thus, no legal statutes exist for R&D units of teaching institutions under the double authority

---

[38]Gvishiani, 1973, p. 202.

[39]Kushlin, 1986, p. 222.

of the Ministry of Higher Education and sectoral ministries.[40]

3.4.2 Inside an institute.

The director of an R&D establishment is solely responsible for running the organization.[41] This is common to all Soviet organizations; what is uncommon is that an advisory body (scientific or scientific-technical council) has a real say in operating the institute.[42] Cases when the councils' decisions are not endorsed by the director are reportedly rare.[43] Scientific councils are said to block directors' attempts to streamline the organizational charts of the institutes.[44] All our sources refer to academic institutes; the power of the director may be less encumbered in sectoral institutes.

In addition to the usual administrative power over the rank and file, the director of an institute also wields power over their research activities: gives approval for publication of their work; and facilitates or constrains their ability to defend dissertations.[45]

---

[40] Mikhailov, 1986.

[41] Gvishiani, 1973, p. 97.

[42] As noted by Gustafson, 1980.

[43] Varshavskii, 1972, p. 12. This may be the result of the councils rarely opposing the director.

[44] Tursunov, 1986.

[45] Ushanov, 1986.

The internal structure of an institute is dictated by tradition and personal preferences of influential researchers, and is slow to change.[46] As with other Soviet institutions, the director of an institute cannot change its internal organization without permission form above. In the academy, changes in the organizational chart of an institute have to be approved by the corresponding division of the Academy and its Presidium.[47] After 1967, sectoral institutes were empowered to establish their internal organizational structure and number of their staff, based on the model structure and number established by the ministry.[48] This new right remained on paper. The limit on the number of employees is still planned from above and tightly enforced (see 3.4.2 below). I do not have evidence on continued ministerial interference in the internal organization of institutes. However, it appears virtually certain to occur, given all other constraints on directors of institutes detailed in this chapter. If the all-powerful first secretaries of regional party committees (<u>obkom</u>) cannot themselves establish the size of particular departments in their apparatus (as one of them complained at the last party congress), institute directors must have even less discretion.

Institute directors face additional constraints in how they can spend their budgets (see 3.5.5 below).

---

[46]Agursky, 1976, pp. 38-40.

[47]Tursunov, 1986.

[48]Motorygin and Sedlov, 1980, p. 79.

Heads of departments, laboratories, and groups make decisions about the resources and direction of work of their units.[49] Rank and file researchers execute the plans laid out by their superiors.[50] To be able to conduct independent research, one has to advance in the administrative hierarchy. According to an impressionistic estimate, young person entering science in the 1980s will have to wait 15 years until being able to do independent research.[51]

One indication of the extent of the bosses' power over the rank-and-file researchers is the fact that they routinely become co-authors with their underlings, irrespective of their contribution.[52] Superiors are also included into patent applications for inventions of their subordinates. Out of all inventors, 55.9% were in administrative positions, while no more than 31% were science workers, engineers, and graduate students.[53]

Vertical mobility in established institutes is slow. In the NII of petroleum refining and petrochemicals sector, researchers are promoted to a higher paying position on average once in 20.7 years, and get pay raise at the same position once in 4.7

---

[49]As noted by Gustafson, 1980, p.

[50]See "Pochemu stareiut ...", 1985.

[51]Gukasov, 1984.

[52]Kitaigorodskii (1985), contrasting organization of science in the West and in the USSR, notes that in the West, scientists have more independence in their research, and science administrators do not become co-authors. See also Kresin (pp. 21-2).

[53]Gliazer, 1975, p. 154, quoting G. Gukov, Sotsialisticheskaia industriia, Aug. 17, 1973.

years.[54] In one eyewitness account of a machinebuilding institute, young researchers were able to advance themselves only in the areas were the old ones completely lacked competence (e. g., computers).[55] Firing for poor performance, raising salary for good performance, or adding positions is very hard for medium-level managers.[56] Since 1968, employees of R&D organizations have been subject to periodic certifications. But this is purely formal, not real. Thus, over the five-year period, 43,000 science workers were recertified (pereattestovany) in the Union Academy; only 110 were considered unfit for their positions.[57]

All institutes are divided into three categories, according to size. Pay scales depend on category. The category designation may be upgraded, but is never downgraded.[58]

The nature of R&D activity, with often unobservable production processes (i. e., inside the researcher's head), creates fertile grounds for shirking. R&D organizations are one of the few places where employees can get by literally doing nothing. And many do.[59]

---

[54]Kugel', 1983, p. 41. The data are apparently for the 1970s.

[55]Agursky, 1976, p. 42.

[56]Kostin, 1983, p. 30 on designers.

[57]"Rech' tovarishcha Sozinova", 1986; Riabushkin, 1985, p. 91.

[58]Rassokhin, 1980, p. 62.

[59]Agursky, 1976, p. 43-4. The employee of an NII who does not do anything has become the regular character of satirical stories published on the 16th page of Literaturnaia gazeta.

3.5 Planning and direction of R&D.

3.5.1 Central planning and management: organs and procedures.

Party organs (CC and local regional committeees) play the key role in appointments of officials responsible for planning and managing science, directors of R&D institutes, and middle management within the institutes.

Plans and budgets of R&D organizations form a part of the national plans and budgets, which are worked out by the Gosplan and Ministry of Finance and approved by the Council of Ministers and the Central Committee of the CPSU.[60] Below this highest level, there are specialized central bodes for planning and directing R&D.

State Committee for Science and Technology (GKNT) was first created in 1947, went through a number of metamorphoses, and emerged in its current shape in 1965. It is the national organ responsible for planning and coordinating R&D activities and implementing innovations in the economy.[61] The main functions of GKNT include:

- producing suggestions for the main directions of scientific research;
- developing 10-15-year forecasts of scientific and technological developments (since 1968);
- compiling and revising every five years, together with the

[60]Nolting, 1978, is an English-language source on planning.

[61]Gvishiani, 1973, pp. 89-92. In English, see Nolting, 1979.

Academy and the State Committee on Construction (Gosstroi), a 20-year complex program of technological progress (since 1979);[62]

- drafting, together with the Academy and planning organs, five-year State plan of R&D (since 1968, the main form of R&D planning), and annual plans;
- preparing, with the Academy, a list of main problems in science and technology to be solved;
- compiling a plan for training of scientists;
- compiling some and approving other complex programs for the solution of main scientific and technological problems (previously, coordination plans); designating head ministries responsible for the entire programs and particular tasks.

GKNT has also the right of overseeing the work of R&D organizations, and has a say in their founding and closing down.

GKNT does not have any line organizations subordinated to it; it is a staff organ, charged with coordinating certain function in the work of line units subordinate to other hierarchies.[63] The internal structure of GKNT corresponds to that of the economy: it consists of departments organized along sectoral lines.[64] This sometimes results in the work of GKNT being con-

[62]"Ob uluchshenii ..", 1982, p. 6.

[63]One exception is the All-union intersectoral NII for protection of metal from corrosion (Rassokhin, 1980, p. 59).

[64]Gvishiani, 1973, p. 91.

ducted along sectoral lines, and in advocacy of sectoral interests, rather than overriding them.[65]

Since much of R&D is planned and directed by the numerous sectoral ministries (see 3.2.2 above), and many important R&D problems have an intersectoral nature, the problem of national coordination of R&D efforts is quite important. The main tool for such coordination is the complex programs, oriented towards the solution of large scientific and technological problems.[66] GKNT compiles such programs and chooses the establishments that carry out particular tasks. GKNT has no power over the executors of the programs, who remain subordinate to, and financed by their ministries and academies.

This administrative fact appears to render the programs largely ineffective. Ministries have to approve programs, which gives them veto power.[67] Some ministries do not include the program tasks into their own plans (in a fifth of all cases of unfulfilled tasks), and divert program resources to other purposes. Some sectoral NII and KB do not even know that they are participating in a program. Nor is GKNT the best judge of what the important problems are, or of ways for solving them. The quality of programs is low: the tasks are formulated in a diffuse, abstract way, and often diverge from customers' require-

---

[65]Rassokhin, 1985, p. 263.

[66]The English-language source on this is Cooper, 1982, pp. 477-490.

[67]Rassokhin, 1985, p. 175.

ments.[68]

Planning and coordination of military R&D is carried out by the Military-Industrial Commission (VPK).[69]

The Union Academy does not only carry out R&D, but is also the body responsible for state policy in the natural and social sciences. It is supposed to oversee, plan and coordinate research in these areas, wherever they are performed (e. g., in teaching or sectoral institutions).[70]

The State Committee of the Council of Ministers for Inventions and Discoveries is responsible for development of inventive activity and utilization of inventions, discoveries, and rationalization proposals in the economy. It operates the equivalent of a patent office, runs an information system on inventions, and selects and recommends inventions for inclusion in state and sectoral plans.[71]

The national plan for industrial products tends to encompass all output of the most important products (steel, machinery, chemicals), if only in the aggregate form. The national R&D plan includes only the most important tasks. Plans of the sectoral ministries and academies include tasks of the national plan, for which they are responsible, and also tasks planned by the minist-

---

[68]Fomin, 1985a.

[69]See Holloway, 1982, pp. 298, 307, and elsewhere in the text.

[70]Gvishiani, 1973, p. 94.

[71]Sbornik, 1983, pp. 51-3.

ry on its own. Main administrations add the tasks of their own, and this completes the plan which is relayed to the R&D establishments for execution.

Ministries also plan total expenditures on R&D in the sector, as a percentage of sectoral output, and the wage bill in R&D as a percentage of expenditures.[72] Total expenditures, or volume of work, subdivided by the source of financing, is the most important indicator in planning of R&D and allocation of resources among different organizations in a sectoral ministry.[73] The typical allocation would be to give similar increments of resources to each of the existing directions of research, so as to preserve existing proportions, and then allocate a small share to start up new direction.[74] The planned number of employees is calculated in most cases based on productivity per employee (in rubles) in the past and the planned volume of work.[75]

3.5.2 Plan targets of establishments.

Since 1979, the five-year plan has been considered the main form of planning for an establishment. However, based on the experience of other sectors of the economy, it is easy to conclude that the annual plan remains the real, operational one. The annual plan is also called "project (tematicheskii) plan".

---

[72]"Ob uluchshenii ...", 1982, p. 28.

[73]Bekleshov, 1986, pp. 92-7.

[74]Rassokhin, 1985, p. 169.

[75]Ianson, 1985, p. 37, 90.

Project is the main unit of planning and accounting for an institute. An R&D organization receives the following annual plan targets:

- the list of projects to be performed;
- total volume of work in rubles;
- volume of work in projects and their stages to be completed in a given year;
- list of testing prototypes to be manufactured at the producer plant;
- plan for implementation of the results of R&D;
- limits on number of employees, total salary, and average salary;
- economic effect of completed projects;
- estimated outlays;
- main investment indicators.[76]

The first two are the most important targets, analogous to the output of main products in physical terms and total output in value terms for industrial enterprises. Completing the main projects (a subset of the total list of projects with the highest priority, usually projects planned by the high authorities) is obligatory; failure to do so may result in sanctions being applied to the organization. After 1979, bonuses for employees of R&D organizations in civilian industrial sectors have been

[76]This is a list for organizations in the Ministry of instruments, computers, and means of automation; see Bekleshov, 1986, p. 73.

tied to the actual economic effect from implementation of results in production per ruble of expenditures.[77] The importance of this plan target therefore has increased.[78]

Before 1967, ministries were given targets (and in turn established those for their NII & KB) for total expenditures, total salaries, average annual number of employees, average salary, funds earmakred for buying equipment, and investment. After 1967, ministries and their institutes were to receive only three targets: total expenditures, wage fund, and sources of financing.[79] Yet, as the list of currently assigned targets shows, the attempt to cut the number of plan targets in R&D was as unsuccessful as in industry.

Enforcement of R&D plans is quite lax. Even the targets of the national plan, the most important ones, were not met by 12% in 1966, 9% in 1967, 11% in 1968, and by an unspecified margin in 1969, and were significantly underfulfilled in 1975.[80] This is much higher than the degree of underfulfillment of annual production plans in industry. Only two plan indicators are strictly enforced (for sectoral institutions): number of employees and

---

77 "Ob uluchshenii ...", 1982, p. 29.

78 Semykin and Bocharov, 1986 state that economic efffect has become the main target for the institutes.

79 Motorygin and Sedlov, 1980, p. 79.

80 Iuzufovich, 1980, p. 35-6, quoting A. Rumiantsev, "Voprosy nauchno-tekhnicheskogo progressa", Voprosy ekonomiki, no. 1, 1971, p. 6, and Pravda, Feb. 8, 1976.

volume of financing.[81]

3.5.3 Planning within an establishment.

R&D planning is an interactive process, with centralized planning agencies obtaining information from the establishments, and allowing establishments some discretion in implementation of plans. We discuss here two aspects of intra-institute planning: choice of projects and planning of expenditures.

All the projects in an institute's plan originate in one of three ways:

- commands from above (as a part of the national plan, a program, ministry or glavk plan);
- contracts with customers (enterprises or ministries);
- suggestions by the researchers of the establishments (i. e., undertaken on own initiative). Officially, head of sectors of the institute's departments can suggest the initiative topic, which then has to be approved higher up.[82]

The planning apparatus described in 3.5.1 must ascertain that research and development needs of the government and its branches are satisfied by the institutes. In sectoral institutions, an order (zaiavka) of glavk or ministry is necessary for inclusion of a project in the plan and the opening of financing.[83] Yet it turns out that all the elaborate planning proce-

[81]Ianson, 1985, p. 37, 90.

[82]Agursky, 1976, p. 45.

[83]Semykin and Bocharov, 1986.

dures constitute no more than a ritual. Almost all projects actually originate with the establishments; the planning hierarchy simply rubber-stamps them. In the beginning of the planning process, R&D organizations receive only general instructions as to the direction of work and problems to be solved. The exact topics are determined by the organization itself.[84] There is practically no explicit public selection of research topics; research establishments never propose alternative choices. Selection takes place within the institutions themselves.[85] "In practice, researchers themselves suggest and plan projects."[86] Most of the projects ordered from above have been previously selected by researchers themselves. This is also true for contracts, since many research institutes have stable relations with the same customers over long periods of time.

How do researchers use this enormous degree of discretion? The topics are suggested so as to best suit the specialization of existing personnel and the existing administrative structure of institutions (departments, sectors, laboratories). The question whether a particular direction of research should be pursued at all is very seldom considered.[87] In most cases, this means the continuation of a topic or direction of research. Almost no

---

[84]Bekleshov, et al., 1986, p. 108.

[85]Shchelishch, 1981, p. 132; Vashchenko, 1986.

[86]Leontieva, 1986.

[87]Struminskii, 1985.

changes in personnel deployment occur with each new plan.[88]

Research projects are planned "from the achieved level", as are so many other things in the Soviet economy. The detailed contents are determined by the scientists themselves, out of intra-scientific or career considerations. The new, emerging directions of research are, as a result, slighted in favor of existing ones.[89] Acceptance of old research topics by the planners reflects their inability to direct R&D in any meaningful way: they do not know what should be done.

Planning mechanism itself serves to deprive the choise of projects of flexibility. In compiling five-year plan, and allocating resources by projects five years in advance, institutes make it hard to accomodate new problems that arise in the course of five-year period. In 1981-85, in the section of physical-technical and mathematical sciences of the Union Academy, only 37% of projects were not envisioned by the original plan.[90]

"Researchers find the contracts with the enterprises that are the best for them. The most important project for the sector will be rejected on the grounds that the department [of research institute - V. K.] already accumulated the required total sum of

---

[88]The most complete account of project selection in branch ministry institutes, based on a survey, can be found in Lakhtin, 1983, pp. 51-58. Gustafson (1980) paints a similar picture for academy institutes.

[89]Viunitskii, 1985.

[90]"Kliuchevaia ... ", 1986a.

contracts."[91] Enterprises and ministries, customers of contract R&D, are indifferent to innovation, and therefore seldom demand any particular projects. They have funds in their budget allocated for R&D, and have to spend these funds in a given period if they are to receive a new allotment. Therefore they go along with the projects proposed by R&D establishments.

Why do research establishments prefer continuation of old topics to new ones?

Keeping stable the administrative structure of the institutes, thus preserving one's own position and power (regarding number of subordinates and budget) is one reason. "Some of our institutes can be compared with early feudal states, consisting of separate small fiefs - laboratories. Everyone tills his individual scientific garden and the worst fear one has is being forced to change topic."[92] In one of the leading NII of the Ministry of fisheries, there is a department developing efficient methods of hunting sea animals. The animals themselves have been almost wiped out, and are now protected, not hunted. Yet the department continues its topic.[93] Here, bureaucratic interests are interwoven with the logic of the system. Since it is administratively hard to fire employees, add new positions, and change the organizational chart (see 3.4.2 above), the easiest conduct for managers is to preserve the existing structure, and this is

---

[91]Leontieva, 1986.

[92]Academician Artsimovich, quoted in Kugel', 1983, p. 85.

[93]Rassokhin, 1985, p. 259.

best accomplished by continuing existing projects.

Another reason for the persistence of old projects is the researchers' desire to defend a dissertation based on this project. Since writing and defending a dissertation is a long process, the project is extended accordingly.[94] Other motives for perpetuation of projects include the convenience of familiar ways of doing things, and the sincere attachment of researchers to particular topics.

The desire to pursue one's own topic, disregarding its status in the field (premature, or obsolete and exhausted) is so ingrained in Soviet scientists that it hampers the adaptation of emigre scientists in the West, where mobility among topics is much greater.[95] It is a curious paradox that Soviet scientists, less free than their Western colleagues in so many respects, are freer to pursue the topics or directions of research in which they have established themselves.

All this does not mean that every researcher receives a topic corresponding to his or her interests. The decision is that of the institution management, or department chiefs. Sociological surveys of researchers in two institutes found that only 20-30% of topics are determined by personal preferences of researchers. The rest are given by instructions of higher organizations and the institution's management; these only rarely

---

[94]"Kazhdyi ..", 1986; also, Pugacheva and Zam, 1986.

[95]See Azbel', 1984.

coincide with the interests of individual researchers.[96]

According to a Gosplan document, ministries are allocated R&D funds before they compiled the list of projects to be performed.[97] Surveys of the institutes of the Ukrainian Academy have shown that R&D expenditures are planned by extrapolating past expenditures. Direct costing of items of future work and special methods of estimating planned expenditures are not used. The total budget of an institute, once established, serves as a benchmark for future expenditures.[98] This reinforces the stability of institutions and topics, outlined above, and also provides a mechanism for the continuous expansion of R&D. If no outlays are ever pared down, and there are always new needs that require additional outlays, the result will be growth of expenditures.

3.5.4 Economic incentives.

Bonuses for the creation of new technology for R&D personnel in civilian industry depend on actual savings (i. e., the economic effect) from implementation of their results.[99] This policy was initially implemented in just one sector, Ministry of Elec-

---

[96]Shcherbakov, 1975, p. 76.

[97]Vashchenko, 1986.

[98]Samoilov, 1972, pp. 21, 23.

[99]"Ob uluchshenii ...", 1982, pp. 29-30.

trotechnical Industry, according to the 1968 decree.[100] It has been gradually spread to msot secotral organizations. Creators of a radically new technology may get the full bonus for the economic effect of the technology in 7-10 years. Until then, they get only 30-40% of the future bonus. For smaller innovations, bonuses can be received within one year; and for innovations for which economic effect is not calculated, the bonus is paid as a percentage of the wage fund.[101]

3.5.5 Financing.

There are four sources of financing R&D: the state budget; the ministries' own centralized funds (formed from the levies on enterprises); the enterprises' own funds; and credit.[102] The budget financing covers part of the academies' research and of the centralized ministry funds. Investment is also centrally allocated. Ministerial funds (EFRNT) formed from budget allocations and levies on enterprises are used to finance the independent NII and KB, and are given to the enterprises for the latter to contract with NII and KB. R&D units of the enterprises that are not classified as R&D are financed by the enterprises' own funds, and accounted for in the overhead expenditures. Those that are considered as part of the non-productive R&D sphere also

---

[100]Gvishiani, 1973, p. 10-110.

[101]Orlov, 1986, p. 36.

[102]English-language source on financing is Nolting, 1976 and 1985.

receive financing from ministry funds.

For R&D establishments, there are two sources of financing: budget (for academic) or ministry fund (for sectoral), and contracts with enterprises.[103] Planning of projects (tematicheskoe planirovanie) and financing are separated. Financing is for institutions, not projects.

Before 1967, ministries were supposed to approve the detailed budget of each institute, including office, travel, and other expenses. The aggregate budget had to be approved by the ministry of finance. Decree of 1967 gave institutes wider discretion in establishing salaries and overhead within the limits given by the ministry; vary expenditures within the broad allocation for R&D; spend savings on wages on equipment purchases; and use 75% of profit from contracts on equipment and materials. There is no need now for an institute to get approval of financial organs for its number of employed, wages structure, overhead budget.[104] Many of these new rights remained on paper. Budget funds are still given to the institutes earmarked for specific uses. These uses are so narrowly defined that in some cases there are almost 20 of them. Institution heads cannot reallocate the funds among these uses on their own.[105] Fewer restrictions attach to disbursement of money received as a payment under

---

[103]Grinchel', 1974, pp. 8-10.

[104]Motorygin and Sedlov, 1980, p. 79.

[105]This is, of course, a phenomenon of "circuit money" (i. e., money that circulates only in a particular closed circuit), common for the Soviet economy. See Katsenelinboigen, ?

contract, than to that of budget funds.

Funds allocated for programmes are disbursed by the participating ministries. They cannot be spent on anything else, but in fact, they are. Forty percent of all cases in which program tasks were not fulfilled were due to diversion of resources.[106] The head organization cannot manouever the funds: all participants are financed by their respective ministries, which are given funds for this particular purpose (tselevym naznacheniem). The head organization does not have economic leverage over the others. Each participant is to a large degree independent of the others.[107]

Current expenditures funds are given quarterly to the R&D organizations. They may be accumulated during a year (for a large purchase); but at year's end, the funds are annulled. Organizations paid for completed work may use their own circulating capital and bank credit; but their own funds are meager, and bank credit is limited by the funds of the customer freed by abolishing quarterly payments (i. e., it boils down to the same thing).[108]

The system of orders for research (zakaz-nariad), first introduced in the Ministry of Electrotechnical Industry after 1968, and now made universal for sectoral R&D, supposes project-

---

[106]Rassokhin, 1985, p. 186.

[107]Nedil'ko, 1985, p. 77-8.

[108]Nedil'ko, 1985, pp. 88-9.

oriented financing.[109] Institutes are paid for finished projects or major stages of projects. In the meantime, they are financed through bank credit (within the limit of funds that the customer would have paid under the old system of quarterly payments). This credit has to be repaid when the institute is paid for the project (out of EFRNT).

3.6 Changes in organization and planning.

One important feature of the R&D sector has been a constant stream of organizational changes. Delving deeply into the substance of each change is impossible in the framework of this study. Some of the changes have already been described in this chapter. What follows is a chronology of these changes.[110]

1947 - a precursor of GKNT was formed and charged with developing R&D plans. These were to be included in the annual plans for the national economy.

1950 - project design and sectoral research institutes were put on budget financing; decreases in contract work, weakening of the ties with production.

1957 - Gostekhnika reformed into GNTK at the Council of Ministers; some of the R&D organizations were subordinated to the regional economic councils, as many sectoral ministries were

---

[109] Riabushkin, 1985, p. 147.

[110] Sources: Motorygin and Sedlov, 1980, pp. 77-81; Oznobin et al., 1971, pp. 38-9; Beliaev and Pyshkova, 1979.

abolished or downgraded.

1961 - April: Following the June 1959 CC CPSU Plenum decision, Council of Ministers returned sectoral institutions to khozraschet. Envisioned 40% of contract work by 1963. Theoretical research and research of national importance still to be financed from the budget.

1961 - State committee of the Council of Ministers for coordination of R&D (control and coordination of ministries and academies; supply of R&D establishments with equipment; scientific information).

1962 - plans for financing of R&D were included into the national annual and five-year plans.

1963 - Division of technical sciences of the Union Academy disbanded, institutes transferred to sectoral ministries.

1967 - Council of Ministers decree of March 22 strengthened khozraschet, broadened the rights of directors of institutes in the spirit of 1965 reform of planning and management in industry.

1968 - Council of Ministers decree of September 24.[111] Obligatory longterm (10-15 years) forecasts of science and technology as a basis for five-year plans. New system for planning, financing, and stimulating sectoral R&D introduced in one sector in Ministry of electrotechnical industry (Minelektrotekhprom). Strengthened the system of bonuses, intro-

---

[111] Nolting, 1976a, is the English-language source on 1968 reform.

duced periodic certification of R&D personnel.

1973 - mergers of R&D organizations with production units into production and science production associations (PO and NPO).

1970s - widening use of complex goal-oriented programs (similar to PPB).

1979 decree - spreading Minlektrotekhprom system to all R&D civilian industrial organizations. Payment for completed projects, bank credit financing.[112]

1983 decree - spread Minelektrotekhprom system to R&D establishments in non-industrial sectors.

[112]"Ob uluchshenii ...", 1982, pp 28-30.

PART II. OUTPUTS.

In this part, trends in the available measures of R&D output are examined, and their reliability and meaning are analyzed. We devote a chapter to each of the two main measures of output, prototypes and patents, and a chapter to assorted other measures.

Chapter 4. Prototypes of New Equipment.

Most new technologies created today are either embodied in new types of machines, apparatus, or instruments, or require those as a complement. (E. g., new products may require new machines to manufacture them.) Prototypes of new machines represent the end product of design and testing, and also incorporate the results of research in technical and natural sciences.

4.1 What is a prototype?

To the best of my knowledge, Western statisticians do not collect data on the number of prototypes created in a given year. For this reason, the concept of prototype used by Soviet statistics needs explanation.

State standards governing the design of equipment define several steps: a mock-up, a model, and an experimental prototype, all leading to the creation of a pilot prototype (opytnyi obrazets). The latter is manufactured according to the newly

produced working design documentation, and is used to test the correspondence of the design to the initial specifications, to correct design documentation, and to prepare the technological process for producing the main parts of the new machine.[1] The creators of the pilot prototype submit it to an acceptance test, in order to establish its correspondence to the specifications and standards, and the possibilities of putting the new model into production. Acceptance tests are conducted by a commission appointed by the ministry which developed the prototype, and/or the ministry that will be producing the new machine. Some acceptance tests are conducted by a state commission - apparently for the prototypes considered the most important. The result of the test is the official decision to recommend or not recommend the model for industrial production. In the former case, additional improvement in the prototype may be prescribed; in the latter case, the commission may recommend additional development work, new testing, or closing the project. The decisions of the commission are then given administrative force in ministerial orders (to start production, to continue development, or cancel the project).[2]

Central Statistical Administration (TsSU) annually conducts a survey which registers all [pilot] prototypes of new machines,

---

[1]Amirov, 1974, p. 99-101.

[2]Amirov, 1974, pp. 137-140. This procedure applies to the prototypes intended for large series or mass production. For those to be produced in smaller quantities, the procedure is simpler (Kamenitser and Rusinov, 1984, p. 53).

equipment, and instruments created during the year (see Appendix A.7). The data from this form are apparently the ones reported in statistical yearbooks. Data on prototypes also serve planning purposes. The list of pilot prototypes to be manufactured at the producer plant is one of the plan targets of R&D organizations.[3] Since 1966, GKNT programs have included targets for the creation of experimental and pilot prototypes (for technologies which have constituted the targets of the programs).[4]

Prototypes of new equipment are designed at independent design bureaus and design bureaus of industrial enterprises (the latter are often not counted in the available measures of R&D).[5] Sectoral NII, research units of teaching institutions, and even some academic institutes design new equipment, as well.

4.2 Creation of prototypes.

4.2.1 General trends.

The most striking feature in the prototype data is the prolonged decline in their absolute number, following extremely fast growth. The number of prototypes of machines and equipment created per year increased about five-fold over the 1950s, and by 20% in 1961-6 (see Tables 4-1 and 4-2).

Table 4-1. Number of prototypes created, units & growth rates,%.

---

[3]Bekleshov, et al., 1986, p. 73.

[4]Lyskov, 1982, p. 138.

[5]For the sake of brevity, we will omit the word "pilot" and use just "prototype" from now on.

Year	Machines, apparatus		Instruments, computers		Total	
1950	650					
1951	559	-14.0				
1952	641	14.7				
1953	740	15.4				
1954	963	30.1				
1955	1056	9.7				
1956	1561	47.8				
1957	1600	2.5				
1958	2051	28.2	348		2399	
1959	2265	10.4				
1960	3099	36.8	942		4041	
1961	3754	21.1				
1962	3164	-15.7	1231		4395	
1963	3229	2.1	1383	12.3	4612	4.9
1964	3113	-3.6	1132	-18.1	4245	-8.0
1965	3366	8.1	1517	34.0	4883	15.0
1966	3605	7.1	1468	-3.2	5073	3.9
1967	3258	-9.6	1288	-12.3	4546	-10.4
1968	2707	-16.9	983	-23.7	3690	-18.8
1969	2983	10.2	941	-4.3	3924	6.3
1970	3007	0.8	1032	9.7	4039	2.9
1971	2939	-2.3	934	-9.5	3873	-4.1
1972	3173	8.0	898	-3.9	4071	5.1
1973	3008	-5.2	961	7.0	3969	-2.5
1974	2970	-1.3	953	-0.8	3923	-1.2
1975	3100	4.4	1070	12.3	4170	6.3
1976	2829	-8.7	966	-9.7	3795	-9.0
1977	2589	-8.5	888	-8.1	3477	-8.4
1978	2941	13.6	924	4.1	3865	11.2
1979	2894	-1.6	880	-4.8	3774	-2.4
1980	2718	-6.1	892	1.4	3610	-4.3
1981	2465	-9.3	779	-12.7	3244	-10.1
1982	2628	6.6	823	5.6	3451	6.4
1983	2830	7.7	800	-2.8	3630	5.2
1984	2709	-4.3	916	14.5	3625	-0.1
1985	2626	-3.1	796	-13.1	3422	-5.6
1986					3500	2.2

Sources: Appendix C; 1986 - "Piatiletke ....", 1987.

The number of prototypes of instruments tripled in 1958-61, and

increased by a half in the early 1960s.

In 1966, the number of prototypes of machines started to decline, and fell by 31.7% to its lowest level in 1981 (the decline from 1985 to 1966 was 27.2%). The decline in the number of instrument prototypes started in 1965 and was steeper than that of machines: 48.6% from 1965 to 1981; 47.5% from 1965 to 1985). That is, the number of prototypes of both machines and instruments in the early 1980s was below that of 1960.

Table 4-2. Number of prototypes of machines and instruments created, and their growth by five-year periods, %.

Period	Total		Machines, equipment, apparati		Instruments, means of automation, computers	
	units	growth rates, %	units	growth rates, %	units	growth rates, %
1951-55	4345		3959		386	
1956-60	12902	196.9	10576	167.1	2326	502.6
1961-65	23178	79.6	16626	57.2	6552	181.7
1966-70	21272	-8.2	15560	-6.4	5712	-12.8
1971-75	20006	-6.0	15190	-2.4	4816	-15.7
1976-80	18521	-7.4	13971	-8.0	4550	-5.5
1981-85	17372	-6.2	13253	-5.1	4119	9.5

Sources: 1976-80, 1981-3 - NKh-83, 100-101; 1951 - 1975 - NKh-79, 112-3.

The decline has not been monotonic, with the annual number of prototypes fluctuating greatly from year to year. It is difficult to reach any conclusions about the change in the speed of decline, except that the decline in the number of instruments has slowed down somewhat in 1976-85 compared to 1966-75.

4.2.2 Machines, equipment, and apparatus.

Machine and equipment prototypes are classified into eighteen groups (see Table 4-3).[6] Each group includes a general type of equipment (e. g., automobiles and tractors; radio and communication equipment), or equipment used by a large sector of economy (equipment for fuels industry, metallurgy, agriculture). Fifteen groups of equipment experienced a decline in the number of prototypes created over the last 30 years. The decline in the number of prototypes is thus a very widely based phenomenon, and cannot be explained by the specifics of a particular sector.

Nine out of fifteen groups had the largest number of prototypes created in the 1961-65 period; only one goup peaked in the late 1950s (equipment for light industry), two in 1966-70, and three in 1971-75. The number of prototypes of more progressive, unconventional types of equipment peaked later than the rest: casting machines, welding equipment, and electrotechnical equipment. Metal-cutting machine tools represent a single traditional technology for which the number of prototypes peaked in 1972 (probably because it got a second breath from numerical control).

Seven groups of prototypes reached a plateau after declining from their peak level. Eight other groups continued to decline (denoted "st. dec." for "steady decline" in Table 4-4). Significant year-to-year fluctuations in the number of prototypes make this classification tentative.

Table 4-3. Number of prototypes of machines and equipment by

[6]Annual data on prototypes by type are in Appendix C.

five-year periods.

Period	Metal cutting machine tools	Forges & presses	Casting machines	Metal-lurgy, mining	Fuels indus-try	Power genera-tion	Electro-technical equipment
1951-55	866	258	36	125	217	124	206
1956-60	1258	512	114	541	574	320	900
1961-65	1306	570	224	677	689	376	2530
1966-70	1537	428	230	568	388	238	2613
1971-75	1872	536	203	573	238	322	2645
1976-80	1646	610	186	460	264	236	2176
1981-85	1348	487	188	530	31*	252	2114

	Trans-port & lifting equip-ment	Automo-biles, tractors, auto-tractor equip-ment	Agricul-tural ma-chines	Chemical, pump, & compres-sor equip-ment	Construc-tion, earth-moving, construc-tion materials industry	Wood-proces-sing & paper-making equip-ment	Light indus-try equip-ment
1951-55	282	61	322	223	225	119	421
1956-60	678	260	616	1104	763	268	744
1961-65	1101	459	955	1932	871	267	740
1966-70	714	194	442	1653	682	254	702
1971-75	674	232	510	1450	510	294	577
1976-80	660	142	439	1236	534	214	489
1981-85	376	299	463	1123	494	174	538

	Food-proces-ing in-dustry	Print-ing equip-ment	Welding & auto-genous equip-	Radio & com-munica-tions
1951-55	214	69	94	97
1956-60	665	119	249	252
1961-65	908	73	291	459
1966-70	656	86	463	407
1971-75	624	69	305	616
1976-80	527	121	312	165**
1981-85	626	84	145*	

Sources: Table C-3; printing, welding, and radio equipment for 1951-1970 - NKh-71, 113. Notes: * - 1981-2 only; ** - 1976 only.

The only group for which prototypes continued to grow through 1976 (after which year no data have been published) is radio and communications equipment. This is both a technologically progressive and heavily military group (both the Ministry of Radio Industry and the Ministry of Means of Communication are defense industry ministries).[7]

Table 4-4. The timing of peaks of machine prototypes created, by group.

Group of equipment	Year of peak	What happened after
Printing equipment*	1956-60	1976-80
Light industry equipment	1956-66	plateau
Fuels industry equipment	1958-66	st. dec.
Construction, earthmoving, construction materials industry equipment	1960-65	st. dec.
Forges and presses	1960-62	1980
Mining and metallurgical equipment	1960	plateau
Food-processing industry equipment	1960	plateau
Wood-processing, paper-making industries	1960	st. dec.
Power generation equipment	1960	st. dec.
Automobiles, tractors	1962	plateau
Agricultural machinery	1962	plateau
Chemical industry equipment, pumps, compressors	1962-66	st. dec.
Transport and lifting equipment	1963	st. dec.
Casting machines	1965-71	plateau
Welding and autogenous equipment*	1966-70	st. dec.
Electrotechnical equipment	1970-75	plateau
Metal-cutting machine tools	1972	st. dec.
Radio & communications equipment	did not peak in 1950-76	

Notes: dates in the last column show second peaks; * - based on the data for five-year periods.

Two groups of prototypes rose to new highs about 20 years after the previous peak. Development of forges and presses has long been neglected in favor of metal-cutting machine tools and thus had ample room for improvement. Printing equipment is a

[7]See Holloway, 1977.

small category which also has been traditionally neglected, but in contrast to forges and presses, is of comparatively priority.

Prototypes data for fifteen groups of equipment are available for every year starting with 1951. This is an unusually good record for Soviet data, but recently it has been marred by cessation of reporting on prototypes of radio and communication equipment (after 1976) and welding equipment (after 1982). The first group is produced by military ministries, so the one should be surprised not by the omission, but by the fact that the data have been published at all. Welding equipment is a large group, produced by the civilian Ministry of electrotechnical industry (though it has important military applications). While there are serious problems with development of this equipment,[8] it is still hard to imagine why the data on this type of equipment are no longer published.

Strangest of all is the story of fuels industry equipment prototypes data. This group should include eqipment for extraction of petroleum, natural gas, peat, and oil shales. The number of prototypes of equipment for the fuels industry declined precipitously from the peak of 202 in 1961 to 30-70 a year after 1967. In 1979-80 it went below 30, and in 1982 just 3 prototypes were created. No data have been published for the subsequent years. This may suggest that the number of prototypes has remained scandalously low, and it was decided to hide this fact. In view of the high priority given to oil and gas exploration and

[8]Communicated by Dr. Boris Rumer.

extraction in the Soviet economy in the late 1970s - early 1980s, this decline is inexplicable. The opposite should have been the case.

4.2.3. The mysterious residual.

The total number of prototypes of machines is larger than the sum of prototypes in each particular group of machines. Prototypes which are not identified with any type of equipment or application constitute 30% of the total number of prototypes (see Table 4-5). To figure out what this residual constitutes, I compare the groups in which prototypes are reported with the standard Gosplan classification of machinebuilding enterprises.[9]

Data on prototypes by group cover all but two classes of civilian machinebuilding outlined in the Gosplan classification, and one group produced in military machinebuilding (radio and communications equipment). The only two civilian machinebuilding sectors for which prototypes are not reported separately are heating, ventilation, air conditioning, and plumbing equipment; and the miscellaneous category (including medical, veterinary, occupational safety equipment).[10] Apparently, the unidentified residual contains prototypes created in these sectors of civilian machinebuilding. But these sectors are too small to account for the size and dynamics of the residual.

It cannot be ruled out that the prototypes created in minor

---

[9]Gosplan, 1974, p. 713-725.

[10]Ibid., pp. 723, 725.

subsectors of a few large sectors of civilian machinebuilding are also relegated to the residual. For example, "machinebuilding for light and food-processing industries" includes, in addition to these two, also restaurant equipment, printing equipment, and electric consumer durables.[11] Prototypes are reported separately for light industry equipment, food-processing equipment, and printing equipment. Are restaurant equipment and consumer durables lumped together with these larger groups (as I would suspect), or relegated to the residual? Similar question may be raised with respect to some subsectors of construction and road-building equipment. Even if these civilian-sector goods are included into the residual, they are too marginal to explain its size and dynamics.

Four major sectors of machinebuilding from the Gosplan classification are absent from the 18 groups of prototypes: aircraft industry, shipbuilding, electronics industry, and defense industry.[12] The obvious reason for this omission is that these are the sectors of military machinebuilding.[13] Prototypes of radio and communications equipment, produced in military machinebuilding, were reported as a separate group through 1976,

---

[11] Ibid., 1974, p. 723.

[12] Ibid., pp. 724-5.

[13] The Gosplan classification is itself incomplete. It does not mention three military machinebuilding sectors: Ministries of General Machinebuilding (strategic missiles), of Medium Machine-building (nuclear weapons), and of Machinebuilding (ammunition). (Holloway, 1982, p. 305.)

after which year they are also counted in the residual. It is natural to conclude that the residual consists mostly of prototypes created in military machinebuilding sectors.

The immediate problem with this hypothesis is that the number of unidentified prototypes was zero in 1951-55. It is impossible that in five years, no prototypes of new equipment were created in military sectors. It should be noted that the early 1950s was a period of reorganization of military production. In 1953, the Ministries of Armaments and Aviation Industry were merged into one, and the Ministry of Shipbuilding was merged with the civilian Ministry of Transport and heavy machinebuilding. In 1954, these mergers were reversed. In 1953, the Ministry of Medium machine building was created, with responsibility for the nuclear program, which was previously directed by the Council of Ministers itself. In 1954, the Ministry of Radiotechnical Industry was created, and in 1955, the Ministry of General Machinebuilding (supposedly for the production of conventional weapons).[14] This series of reorganizations may have had something to do with changes in reporting procedures. It is possible that prototypes of military equipment created during this period were not reported, or were spread among the civilian sectors. If the former has been the case, then the rise in the total number of prototypes in the late 1950s was not as rapid as our data show; rather, it partly reflects the inclusion of previously excluded types of equipment.

[14]Holloway, 1982, pp. 304-6.

If the latter has been the case, than the surge in the number of prototypes in civilian sectors in the late 1950s has been even greater than shown by the data.

We cannot be sure that all prototypes created in military sectors are counted in the residual; some may be lumped with civilian sectors prototypes, and others may go uncounted altogether.

Instruments are classified according to function (radio measurement instruments, electric measurement instruments, computers, etc.). The Gosplan classification states explicitly that instruments produced in the military sectors are counted in the corresponding functional class.[15] Therefore, when prototypes of instruments were reported by group in 1958-70, the sum of all groups was equal to the reported total number of prototypes. There was no residual.

We conclude that the residual number of unidentified prototypes of machines relates mostly (though not only) to the prototypes created in military sectors. (A distinction should be maintained between the military and civilian sectors and military and civilian goods. Some military equipment is produced by non-military sectors (e. g., vehicles by the Ministry of Automobile industry).[16] One may assume that they are also designed by the corresponding sectors, and the prototypes are classified accordingly. On the other hand, military machinebuilding ministries of

[15]Gosplan, 1974; p. 718.

[16]Holloway, 1977, p. 309.

design and produce civilian goods (cargo ships, passenger planes, etc.)

We subtract the number of prototypes of radio and communications equipment created in 1951-75 from the total number of prototypes in civilian sectors, and add it to the residual. (For years after 1975, this group is already counted within the residual). This makes coverage of residual and total civilian prototypes more consistent, and eliminates prototypes created in military ministries from the civilian total.

The trends of the residual number of prototypes are markedly different from those of the civilian sector prototypes (denoted "itemized" in Tables 4-5 and 4-6).

Table 4-5. Total, itemized, and residual numbers of prototypes of machines, equipment, and apparatus.

Period	All prototypes	Itemized	Share of itemized in total	Itemized w/o radio & communications equipment	Residual	Residual + radio & & communications equipment
1951-55	3959	3959	100.0	3862	0	97
1956-60	10576	9937	94.0	9685	639	891
1961-65	16626	14428	86.8	13969	2198	2657
1966-70	15560	12255	78.8	11848	3305	3712
1971-75	15190	12250	80.6	11634	2940	3556
1976-80	13971	10417	74.6	10417	3554	3554
1981-85	13253	9272	70.0	9272	3981	3981

Sources: Appendix C: Table C-3.

The residual number of prototypes grows in 1956-65 much faster than civilian prototypes. For 1956-60, this may be attributed to peculiarities of reporting: there were no prototypes reported in this category in 1951-55, except for radio and communications equipment. The number of prototypes created in

civilian ministries has been declining by substantial margins in every five-year period after 1965. The residual (plus radio and communications equipment) number of prototypes grew in 1966-70, declined only slightly in 1971-75, and remained unchanged in 1976-80.

Table 4-6. Growth rates of total, itemized, and residual prototypes of machines and equipment by five-year periods, %.

Period	All prototypes	Total itemized	Itemized w/o radio & communications equipment	Residual	Residual plus radio & communications equipment
1956-60	167.14	151.00	150.78		818.56
1961-65	57.20	45.19	44.23	243.97	198.20
1966-70	-6.41	-15.06	-15.18	50.36	39.71
1971-75	-2.38	-0.04	-1.81	-11.04	-4.20
1976-80	-8.03	-14.96	-14.96	20.88	-0.06
1981-85	-5.14	-10.99	-10.99	12.01	12.01

Source: Table 4-5.

In 1981-85, the residual shows a 12% increase, compared to the 10% decline of the civilian total. These data have to be adjusted for the fact that after 1982, prototypes of welding equipment are no longer reported as a group, and hence inflate the residual. Let us assume that in 1983-5, the number of prototypes of welding equipment created annually was the same as in 1981-2. We then add the assumed number of welding equipment prototypes in 1983-5 to the total of civilian ministries, and subtract it from the residual. With this adjustment, the civilian total in 1981-85 still declines by 8%, and the residual grows by 6%. This suggests that the direction of change of the two magnitudes is not influenced by the change in reporting of welding equipment. Residual prototypes continue to grow, while

civilian-sector prototypes continue to decline.

In the last twenty years civilian-sector and residual prototypes have been moving in the opposite directions. Fewer and fewer of the former and more and more of the latter have been created each year. The downward trend characterizes not only the total number of civilian-sector prototypes, but also fifteen out of seventeen particular groups of equipment. In contrast, data for radio and communications equipment prototypes, the only military-sector group separately reported, show steady growth through 1976.

Military sectors are among the most technologically progressive (electronics, radio, aircraft). It may be the case that there was more opportunities for new design in these sectors than in the older ones such as metallurgy and mining; that R&D in defense sectors fared better because these sectors are more technologically progressive, not because they are defense. However, instruments, means of automation, and computers, which are no less technologically progressive than any of the military sectors, experienced a marked decline in the number of prototypes created.

This suggests that R&D fared better in the military than in civilian machinebuilding because it was receiving a larger share of total resources: more and better researchers, designers, experimental and testing equipment. It may also be the case that R&D organizations in military machinebuilding have been using their resources more efficiently than their civilian counter-

parts, though I do not see why this should be so.

It also follows that the decline in the number of prototypes of machines created in the last twenty years is almost entirely due to the prototypes of civilian-sector equipment.

The value of our analysis depends on the correctness of its main assumption: that the unidentified residual of prototypes of machines represents mainly military machinebuilding sectors. We first argued in favor of this assumption by contrasting the groups in which prototypes are reported with standard classification of machinebuilding plants.

Contrasting the dynamics of the number of prototypes idenitified with civilian sectors, and the residual, offers an additional argument in favor of our hypothesis. While the number of prototypes in almost all civilian groups is declining, the residual number of prototypes keeps growing. Below we will show that prototypes in the residual are much more likely to be put into production. All this suggests that the residual does not represent just some minor leftovers of civilian machinebuilding; it represents very strong, vibrant sectors with different resource availability and/or efficiency, and a different organizational environment. This can only be military production sectors.

Soviet statistical organs make sure that analysis of the sort presented here can never be conclusive. One way to test our conclusions would be to show them to specialists in military hardware, and other experts on Soviet military machinebuilding.

4.2.4 Instruments, computers, means of automation.

Prototypes of instruments are reported by particular group only for 1958-70. The largest single group of instruments, process control devices, peaked in 1963, and threafter drastically declined. (See Table 4-7 for trends, and Table 4-8 for the size of particular groups). A comprehensive survey of process control developments in the USSR characterizes the late 1960s as a period of virtual stagnation on a quite backward level, and standardization as continually poor (except for controls for power generation).[17] Decline in the number of prototypes did not bring any improvements in their quality.

Five more groups peaked in 1965-1967, and declined thereafter. A small group, optical-mechanical instruments and apparatus (which must include photo cameras), showed no clear trend in 1958-1970. The only two groups which continued growing through the 1960s were computers and medical and biological instruments, still small at the time, but on the cutting edge of technological progress.

It appears that the decline in the number of prototypes of instruments is as broad-based as that of machine prototypes, affecting most of the groups of instruments.

---

[17] Siemaszko, 1977.

Table 4-7. New types of instruments created.

Year	Optical-mechanic. instruments & apparatus	Electric measurement instrum.	Radio measurement instrum.	Computers	Process control instrum.	Mechanical measurement instrum.
1958	22	77	36	9	73	100
1960	89	125	41	41	322	216
1962	46	136	47	25	644	201
1963	27	129	67	48	768	200
1964	70	85	93	45	482	240
1965	88	153	96	68	569	276
1966	85	202	59	65	514	329
1967	66	151	115	67	397	315
1968	52	172	72	41	346	179
1969	88	126	77	61	286	151
1970	51	105	58	71	403	165

Source: NKh.

Table 4-7. Continued.

	Time instruments	Instruments for physics research	Medical, physiological, biological instruments
1958	6	23	2
1959			
1960	9	85	14
1961			
1962	18	80	34
1963	21	73	50
1964	19	58	40
1965	32	190	45
1966	22	134	58
1967	35	124	18
1968	10	81	30
1969	18	81	53
1970	21	83	75

Table 4-8. Structure of instruments prototypes, shares, %%.

Year	Optical-mechanic. instruments & apparati	Electric measurement instrum.	Radio measurement instrum.	Computers	Process control instrum.	Mechanical measurement instrum.
1958	6.32	22.13	10.34	2.59	20.98	28.74
1960	9.45	13.27	4.35	4.35	34.18	22.93
1962	3.74	11.05	3.82	2.03	52.32	16.33
1963	1.95	9.33	4.84	3.47	55.53	14.46
1964	6.18	7.51	8.22	3.98	42.58	21.20
1965	5.80	10.09	6.33	4.48	37.51	18.19
1966	5.79	13.76	4.02	4.43	35.01	22.41
1967	5.12	11.72	8.93	5.20	30.82	24.46
1968	5.29	17.50	7.32	4.17	35.20	18.21
1969	9.35	13.39	8.18	6.48	30.39	16.05
1970	4.94	10.17	5.62	6.88	39.05	15.99

Source: Table 4-7.

Table 4-8. Continued.

Year	Time instruments	Instruments for physics research	Medical, physiological, biological instruments
1958	1.72	6.61	0.57
1960	0.96	9.02	1.49
1962	1.46	6.50	2.76
1963	1.52	5.28	3.62
1964	1.68	5.12	3.53
1965	2.11	12.52	2.97
1966	1.50	9.13	3.95
1967	2.72	9.63	1.40
1968	1.02	8.24	3.05
1969	1.91	8.61	5.63
1970	2.03	8.04	7.27

4.3 The lack of prototypes hurts the economy.

Does a decline in the number of prototypes signify a decline in the output of development? To find this out, we will try to answer a number of related questions: has the decline been good or bad for the economy? Was it a planned or unexpected decline? Are there too many or too few types of machines in the economy?

4.3.1 The number of prototypes limits the number of new models produced.

It is in the nature of R&D activity that some of its output will not be usable (see 2.3 above). The initial weeding out of prototypes occurs at the stage of acceptance tests conducted by a commission appointed by the ministry (see 4.1 above). Sketchy data on the rate of acceptance of prototypes are presented in Table 4-9.

Table 4-9. Prototypes accepted for production as a share of prototypes created, %.

	Ukraine(1) 1971	1966-(2) 1970	1971-(2) 1975	1971-(3) 1980
Machines & equipment	85			70
Instruments	<90			
Total		65	73	

1 - Marin and Pavelko, 1974, p. 35; 2 - Bliakhman, 1979, p. 228; 3 - Pokrovskii, 1983, p. 132, as quoted in Beshelev and Gurvich, 1986, p. 41.

Prototypes that are accepted by the commission and recommended for industrial production may prove unusable in the process of preparation for production. Thus, in 1980, about 17% of the models of new technology were rejected, since it was disco-

vered in the process of preparation for implementation that they needed additional development and testing.[18]

Even if a prototype has been a success from the R&D point of view, it may be wasted for the economy. A prototype that has been recommended for production may never get into the production plan because of lack of interest on the part of producers, irrespective of its quality. In the 1970s, 21% of accepted prototypes were put into production in the same year; 34%, in the next year; and 11% in the third and subsequent years.[19] Prototypes put into produc-tion today may have been created a long time ago.

Table 4-10. Prototypes put into production as a share of all prototypes created, %.

Year	Total	Machines	Itemized machines	Residual machines	Instru-ments
1966-70	31.97*				
1971-75	55.10	60.11	59.14	62.82	39.33
1976-80	65.20	66.80	55.70	92.34	60.31
1981-85	75.75	70.78	62.06	88.82	91.75
1980	71.63	70.75	58.37	96.70	74.33
1981	77.25	82.07	57.83	132.05	62.00
1982	63.69	52.85	57.06	43.85	98.30
1983	73.83	58.73	55.69	65.07	127.25
1984	80.33	75.97	71.09	85.67	93.23
1985	83.69	85.64	68.80	120.23	77.26

* - this share is likely exaggerated; the number of prototypes put into production may include items other than machines and instruments.

In the late 1960s, less than one third of all prototypes

[18] Koriagin, et al., 1983, p. 88.

[19] Bliakhman, 1979, p. 228. Beshelev and Gurvich, 1986, p. 41, quote from Pokrovskii, 1983, p. 132, different distribution: 20%, 30%, 18%, and 32% - in the fourth year and beyond.

were put into production (Table 4-10). This was due primarily to the low share of instrument prototypes implemented, but the share of machine prototypes implemented was also almost certainly below 50%. This implies a tremendous waste of R&D effort. The rate of acceptance of prototypes did not change significantly from the late 1960s to early 1970s (see table 4-9). The low rate of implementation in the 1966-70 was due to the underutilization of prototypes that were already accepted. Many more prototypes were produced than industry needed, or cared to implement. We do not know what the situation was in the 1950s, but it may be conjectured that as the number of prototypes created soared, their rate of implementation plummeted. The innovative output of the R&D sector was outstripping demand.

Over the last 20 years, the share of prototypes implemented more than doubled. This was caused by the steep increase in the share of instrument prototypes and a significant increase in the share of residual machine prototypes implemented.[20] The share of civilian machine prototypes implemented shows no trend over the last 15 years (though it must have increased from 1966-70 to 1971-75). The rate of implementation of residual prototypes was only slightly higher than that of civilian-sector machine prototypes in 1971-75. In 1976-85, it became higher by about 50%. The rate of implementation of instrument prototypes reached the same level as the residual (90%) in 1981-85.

---

[20]In this section, residual includes prototypes of welding equipment; data on prototypes implemented do not allow us to separate it.

The rate of implementation of prototypes of instruments soared as the number of prototypes created declined, while the number of prototypes used grew strongly in 1976-85 (Table 4-11). The rate of implementation of residual machine prototypes jumped in 1976-80, when the number of prototypes put into production increased by over 50%. As for civilian sector machines, prototypes put into production declined in 1976-85, as the number of prototypes created was declining, keeping the rate of implementation nearly stable.

Table 4-11. Rates of growth of the number of new models put into production, % (by five-year periods and annual).

	Total	Machines	Itemized machines	Residual machines	Instruments
1971-75	62.12				
1976-80	9.54	2.21	-18.11	55.99	44.88
1981-85	8.98	0.53	2.17	-1.77	37.72
1981	-3.09	5.20	-10.61	25.21	-27.15
1982	-12.29	-31.34	6.46	-65.48	67.49
1983	21.93	19.65	4.31	62.40	25.83
1984	8.66	23.83	20.17	30.37	-16.11
1985	-1.65	9.28	-5.15	33.08	-27.99

Source: NKh.

While the rate of implementation of all civilian-sector prototypes remains stable, the rates of particular groups move in different directions: increase (metal cutting machine tools, power generation); no change (metallurgy and mining, electrotechnical, and chemical, pump, and compressor equipment); decrease (forges and presses, casting machines, transport and lifting, automobiles and tractors, agricultural equipment). (See Table 4-12).

Table 4-12. Number of new models of machines put into series production as a share of prototypes created, by type, %.

Period	Metal cutting machine tools	Forges and presses	Casting machines	Metallurgy & mining	Power generation equipment	Electrotechnical equipment
1971-75	37.82	48.13	55.67	49.91	44.10	65.42
1976-80	44.47	35.25	13.98	46.74	47.46	69.99
1981-85	66.62	32.24	31.91	53.58	48.81	69.54
1980	53.00	21.39	11.11	46.67	50.94	68.94
1981	71.91	23.48	66.67	37.80	24.53	70.84
1982	64.94	23.97	10.00	33.33	31.82	62.95
1983	63.04	37.50	34.29	57.85	62.00	52.85
1984	66.67	43.59	27.78	72.50	79.59	87.38
1985	66.92	45.00	17.14	61.46	46.43	77.92

Period	Transport & lifting equipm.	Automobiles, tractors, agricultural equipment	Chemical, pump, compressor	Construction, earthmoving	Wood-processing, papermaking	Light industry equipm.
1971-75	59.50	66.44	78.00	86.16	30.95	70.02
1976-80	50.61	82.44	69.58	37.54	32.71	47.65
1981-85	59.04	40.29	86.20	61.03	27.59	67.29
1980	65.29	91.43	67.11	76.92	39.29	41.30
1981	72.17	40.63	69.76	63.33	7.14	41.38
1982	31.17	57.30	80.66	61.97	23.68	70.75
1983	43.04	34.57	76.33	56.06	55.00	64.60
1984	82.05	37.44	91.60	55.00	62.07	88.18
1985	74.24	40.20	111.66	72.22	15.56	66.39

Period	Equipment for food-processing	Printing equipm.	Construction materials	Total itemized	Residual
1971-75	45.03	75.36	32.29	59.14	62.82
1976-80	33.78	66.12	34.05	55.70	92.31
1981-85	44.25	103.57	48.47	62.06	88.82
1980	45.71	71.43	48.57	58.37	96.70
1981	33.33	63.64	82.61	57.83	132.05
1982	46.85	133.33	39.13	57.06	43.85
1983	32.69	191.67	27.66	55.69	65.07
1984	46.15	58.82	57.78	71.09	85.67
1985	60.43	106.67	48.00	68.80	120.23

Source: NKh.

The rate of implementation is consistently high (above 2/3) in chemical, pump, and compressor equipment; electrotechnical equipment; and printing equipment. It is consistently below 1/3 in wood-processing and paper-making.

It is noteworthy that no group of civilian-sector prototypes has a 90% rate of acceptance for any five-year period.[21] Yet this is the average rate for the residual machine prototypes and for instruments. Machines in the residual as a group are hardly different technologically from civilian-sector machines. Their higher rate of implementation must be explained by organizational differences in military and civilian machinebuilding.

Military machinebuilding R&D may have better designers, superior testing and experimental facilities, and more people on the same project, and as a result, produce better prototypes that pass acceptance tests more easily than those in civilian sectors. Relations among designers, producers and customers in military machinebuilding are different from those in civilian sectors. Designers and especially customers have more of a say about what is being produced, and are better able to force producers to adopt new designs. As a result, a larger share of accepted prototypes may actually be put into production.

Instrument prototypes represent a set of technologies different from those of machines, and therefore are probably not comparable with the latter. The only piece of data available suggests that the rate of acceptance of instrument prototypes is

[21] Printing equipment in 1981-85 is the only exception.

higher than that of machines (Table 4-9).

The rate of implementation of prototypes of residual machines in the last ten years and of instruments in the last five years is extremely high. Let us assume that the rate of acceptance for these prototypes is 90%, which is unrealistically high judging by the numbers in Table 4-9. This would mean that every prototype created has to be put into production immediately to maintain the current level of introduction of new models. But the rate of acceptance may be lower than 90%; some accepted prototypes turn out to be unusable; and still others take several years for implementation. This means that currently, the number of prototypes of military sector machines and instruments created is less than what industry would like to (or is ready to) put into production. The situation may be softened for a while by the backlog of prototypes created in the past, now being put into production. One reads occasionally of plants being constructed to ten-year old designs. Since ten years ago there was an excess of prototypes created over the number actually used, some of the old prototypes may be finding their way into factory floors now. This is only a short-run cushion.

The number of new models of military sector machines and of instruments produced by industry is now limited by the capacity of R&D to produce new prototypes. In the case of instruments, the decline in the number of prototypes is at fault; in the case of military sector machines, the number of prototypes has not grown fast enough to keep pace with the needs of production.

This must be the primary reason why the number of new models of military-sector machines produced in 1981-85 did not increase. Without a radical increase in the number of prototypes of instruments created, the number of new models of instruments produced will not go further in 1986-90.

The number of new models of civilian sector machines in 1981-85 was much below the level of 1971-75, despite the still seemingly benign rate of implementation (around 60%). This decline is probably due not to lack of prototypes, but to the lack of interest on the part of civilian-sector management, and possibly, to low acceptance rates and low quality of accepted prototypes.

4.3.2 The economy needs more new models of machines than currently produced.

We have demonstrated that the increase in the number of new military-sector machines and instruments is limited by the availability of prototypes. Here, we will show that the economy suffers from the lack of new civilian sector machines, which can be traced to lack of prototypes.

New types of equipment are needed for two reasons: to replace obsolete ones performing the same function, and to perform new functions. The number of products in the economy is increasing.[22] In particular, the number of products of Ministry of

[22]Efimov, et al., 1985, p. 28.

instruments has recently been growing very fast.[23] However, the number of new models does not grow fast enough to satisfy the needs of the economy.

The economy is not getting enough new models of equipment to replace the older ones. The share of new models in the total output of machinebuilding has been declining since 1966, and the share of old models has been increasing.[24] The lack of new models is not the only cause of the aging of machinebuilding output. In the early 1970s, the number of new models put into production increased drastically, but the age of output fell nevertheless. (Apparently, new models were being produced in smaller quantities, and old products, in larger quantities). But the drastic slowdown in the growth of the number of new products in 1976-85 could not but contribute further to the aging of machinebuilding output. "Mechanization of the whole economy requires 100,000 types of machines. With obsolescence on average at least in 10 years, this means the economy needs 10,000 new machines a year, while it is getting only 40% of this number."[25]

There is abundant evidence that machines for many necessary functions do not exist. Machinebuilding does not produce the required variety of models, types, and sizes of equipment, which forces inefficient use of existing machines. The general rule is that there are no specialized, very small and very large machin-

---

[23] Shkabardnia, p. 12, 1986.

[24] Kontorovich, 1985, pp. 290-295; 1986, p. 182.

[25] Leshchiner, 1979, p. 25.

es, and their functions are performed by universal machines of medium capacity. Metal-cutting machine tools are too powerful; coal mining equipment for narrow, wide, and steep seams of coal does not exist; in the petroleum sector, there is no equipment for shallow drilling; the fleet of trucks, bulldozers, and excavators is dominated by medium-size models, while large and small models are lacking; there is no miniature agricultural equipment; small size construction equipment, especially hand-held, is lacking.[26]

"The mix of the equipment produced does not fully satisfy the requirements of some sectors, especially of food processing, light industry, chemical and petrochemical industry, fuels, and others. Though qualitative characteristics of the new machines are the most important, the quantitative aspect should not be neglected, in view of the significant decline in the number of new machines for metallurgy and mining, foodprocessing, light industry, fuels, transport equipment, chemicals, pumps and compressors."[27]

Over the last 20 years, practically nobody has been developing mechanisms specifically for the hydroelectric construction.[28] Railroads are lacking new types of locomotives, because of long delays in development. In petroleum machinebuilding, 270 new types of equipment will have to be created and put into

[26]Palterovich, 1984, p. 60.

[27]Yampol'sky and Galuza, 1976, p. 25.

[28]Bogatko, 1985.

series production in 1986-90.[29] But only a handful has been created recently (see "Fuels industry" in Table 4-3 above). There is a lack of new types of forging machines and presses, due in part to delay in production of prototypes.[30]

There are direct complaints about the slow pace of development of prototypes of new machines and instruments.[31] Further development of machinebuilding is said to require an increase in the number of prototypes of new models, and more reasonable ratio of created and implemented machines.[32]

It may be concluded that the decline in the number of prototypes of machines and instruments hurts the economy. Obsolete models are not replaced; machines are utilized in irrational regimes; no machines exist for many important functions. The R&D sector has become a constraint on further economic development.

4.3.3 There are too many models of similar equipment.

Shortage of goods and services is never absolute; shortage in some sectors exists side by side with slack in other sectors.[33] The shortage of new prototypes outlined above coexists with excessive proliferation of prototypes. The latter arises

---

[29]"Rech' tovarishcha Dinkova", 1986.

[30]"V Komitete ...", 1986.

[31]"V Politburo ...", 1987.

[32]Fal'tsman, 1985, p. 14.

[33]This idea is developed by J. Kornai in his writings on shortage.

because ministries and enterprises tend to design and produce machines for their own needs.[34] Many different organizational units are developing different prototypes and producing different models of machines that perform the same function. Here are some instances of overabundance of models of machines (hence, prototypes).

"Many automobile, tractor, and other large machinebuilding plants design new products in-house .... a large number of similar machines and mechanisms of different design are being created. E. g., diesel engines are being produced by the plants of seven ministries. ... This causes, among other things, the increase in the number of products."[35]

Out of twenty types of compressors with output pressure of 8 atm many have similar productivity. The same is true for filters, pumps, and other types of equipment. This is the result of duplication in design. Too much effort of designers goes towards creation of more new types of equipment, at the expense of their quality.[36]

Six different types of internal combustion engines are used for mobile electric generators. Producers of electric aggregates have to manufacture six different types of machines with the same capacity, to accomodate different types of engines. Fourteen

---

[34]The tendency enterprises to put into productiion only own designs, and to spurn the designs made even by the insitutes of the same ministry was noted by Agursky, 1976.

[35]Volkov, 1975, p. 223.

[36]Fabrichev, 1978.

types of diesel motors for mobile electric generators with capacity of 100 kilowatt are produced, though two types would be enough. The same is true for generators with 30 kilowatt capacity. The root cause of proliferation is that each ministry makes machines for its own narrow use; nobody wants to produce for all sectors.[37]

Stricter standardization and better coordination among sectors which will eliminate this sort of duplication will cause a decline in the number of prototypes of new equipment, but will also benefit the economy. Could it be that the observed decline in the number of prototypes produced is due wholly or in part to such standardization? If so, the decline did not hurt the economy, since the prototypes that were eliminated were not needed.

While I cannot at this point exclude such a possiblity, it seems unlikely. The root cause of duplication, departmental segmentation and the attendant tendency for self-procurement, were not becoming weaker in the late 1960s and the 1970s. Complaints about excessive proliferation of models include some quite recent examples.

4.4 Conclusion.

We have tried to show the consequences of the decline in R&D output for the economy. But this does not say anything about its causes. The decline has hurt the economy; most likely, it was

---

[37]Gorokhov, 1986.

not a planned or predicted process, and there are attempts now underway to reverse it. The R&D sector's failure to meet the needs of the modern economy does not necessarily mean that the productivity of R&D declined. There are at least two alternative explanations.

Successive models of equipment based on the same technological principle have a higher unit capacity, larger size, and greater complexity. For this reason, prototypes twenty years ago may not be comparable to current ones. More recent prototypes may embody higher quality, and therefore a decline in number of prototypes does not necessarily mean a decline in output. It is only reasonable to expect that more complex, powerful, and larger machines take longer to design.[38] Not all technological progress leads to more complex and larger machines that are harder to design. There are undoubtedly examples of superior technologies that are simpler than their predecessors. Nevertheless, it seems certain that the increased complexity of machines explains at least some of the perceived decline in R&D productivity in terms of prototypes. We only claim that this is not the only cause of decline in prototypes per unit of input; that there are other forces at work which can be properly labeled as decline in productivity of resources.

Labor intensity of design and development is significantly larger for products destined for series production than for

---

[38] Effektivnost', 1977, p. 17

unique and small batch products. The former have to be designed so as to be easy to produce, for the latter, this requirement is not important. For instruments, the difference in labor intensity in design between unique and series production items is 1.5-3 times.[39] The larger the share of series production in the total number of models, the lower productivity will be. Unfortunately, there are no data on change in the share of unique machines over time.

We will analyze some of the causes of decline in prototypes per unit of R&D input in subsequent chapters. Here, we would like to display the views of Soviet researchers on the subject. They rarely elaborate on the causes of decline in the number of prototypes, but rather express a general sense of trouble over it.[40] This is important because Soviet authors have access to much more complete data than we do, and also to opinions of experts in particular technical fields. Quotations below are our only chance to glimpse this information.

"Decline [in the number of prototypes created] reflects the increasing requirements to modern equipment, but still it is worrisome."[41]

"The trend of the increasing number of models created per employee of NII and KB upwards before 1960 and downwards in

---

[39] Ianson, 1985, p. 39.

[40] Palterovich (1984, p. 57) considers the decline "a negative trend".

[41] Leshchiner, 1979, p. 25.

1961-1971 characterizes some decline in efficiency of labor in science."[42]

The decline in the number of models of new products is named as one of the causes of the labor productivity growth slowdown and of increasing capital intensity of production.[43]

---

[42] Grinchel', 1974, p. 79.

[43] Koriagin et al., 1983, p. 88.

Chapter 5. Inventions.

An invention is defined as a "new and significantly different solution to any economic, social or cultural problem that yields positive effect".[1] To qualify as an invention, a technological solution has to pass an examination by patent experts who test its novelty and usefulness. The interpretation of the "novelty" requirement by Soviet experts has been discussed in 1.3 above. The requirement of "usefulness" means that in order to get a patent, the applicant has to demonstrate the practical advantages of the proposed technology over the relevant existing one. This may be impossible for many patentable ideas without a great deal of complementary developments.[2]

5.1 Trends in patenting.

The patents granted reflect the end result of inventive activity. Applications for patents and the share of applications approved (approval rate) describe the processes that lead to this end result. The number of applications characterizes the volume of creative effort, and/or pressure to patent, generated by the organizational environment. The rate of approval characterizes the quality of creative effort, and/or stringency of standards used by patent authorities in judging applications. We use

---

[1] Sbornik, 1983, p. 19. For an English-language description of the Soviet patent system, see Martens, 1983.

[2] Kolesnikov and Starovit, 194, pp. 124-5.

changes in the number of applications and in the rate of acceptance to explain changes in patents granted.

In the early 1950s, the number of patents granted each year declined 3.5 times, as both the number of applications for patents and the rate of their acceptance were halfed (annual data on patenting are in Table 5-1; the summary of trends is in Table 5-2). I have no explanation for this strangely precipitous decline. A special investigation would be needed to establish whether it was due to a sudden collapse of the quantity and quality of inventive effort, or decline in the pressure to patent.

In the late 1950s, the number of patents began to grow, and by mid-1960s reached the level of 1950. This growth was caused entirely by the increase in the number of applications, with the rate of approval remaining low. The next stage of growth, from the mid-1960s through mid-1970s, witnessed more than a three-fold increase in the number of patents, caused by a doubling of the rate of approval and a 50% increase in the number of applications. It is only then that the rate of approval finally reached the level of 1950. As data in Table 5-4 show, savings from an average *implemented invention* declined by a factor of almost 2 around 1968. If this is taken as an indication of decline in the quality of patents granted, than the rate of approval was increasing at least partly because of relaxation of standards, and not because of higher quality of applications.

Table 5-1. Patent applications, patents granted, and rate of approval of applications.

Year	Number of patents, thous. applied for	granted	Share of applications accepted %
1950	32.5	11.6	35.7
1955	18.8	3.3	17.6
1958	36.3	8.1	22.3
1960	53.9	10.5	19.5
1961			18.0
1962	71.3	10.7	15.1
1963			11.1
1964	94.2	11.2	
1965	95.0	13.8	14.5
1966	98.5	15.9	16.1
1967	100.5	21.5	21.4
1968	110.4	24.9	22.6
1969	119.0	31.3	26.3
1970	132.5	38.0	28.7
1971	153.9	43.7	28.4
1972	155.5	46.8	30.1
1973	163.3	43.3	26.5
1974	143.4	44.1	30.8
1975		33.1	
1977	130.5	70.8	54.2
1980	169.0	103.0	61.0
1981	154.0	81.0	52.6
1982	154.0	77.0	50.0
1983	147.0	71.0	48.3
1984	146.0	82.0	56.2
1985	157.0	86.0	54.8

Sources: Patent applications submitted and patents granted from Artem'ev, Kravets, 1977, p. 47. Share of patents granted in 1961-3 from Zvezhinsky, 1968, p. 128. 1975 patents calculated by subtracting Artem'ev, Kravchenko data for 1971-4 from NKh-84 data for 1971-5. Similar calculation for the number of applications gives negative number for 1975. 1950, 55, 58, 62, 64 - Dobrov, et al., 1969, pp. 104-7. 1960 - Maskarev, 1969, p. 19. 1980-3 - NKh-83, 99; 1984 - NKh-84, 108; 1985 - NKh-85, 68.
Note: data for 1977 are annual average for 1976-79 derived from NKh-83 data for 1976-80 and 1980.

The number of patents granted declined somewhat in 1973-5, because of reorganization of the work of the State committee on inventions.[3] The number of applications also declined, with a one-year lag. In the late 1970s, the number of patents granted more than doubled (from 1972 to 1980). This occurred without any significant increase in the number of applications, due to doubling of the rate of acceptance. This would mean either a sudden increase in the quality of patent applications, or a relaxation of standards for patenting. It is unlikely for patent quality to improve so abruptly. The fact that the rate of acceptance increased immediately after the reform of the patent system, and some qualitative evidence cited below, suggest that there was a relaxation in standards applied by the patent office.[4]

Table 5-2. Periodization of trends in inventive activity.

	Annual number of:		
Period	Applications	Acceptance rate	Patents
1951-55	declined 40%	declined 50%	declined 70%
1956-63	increased 4-fold	no trend	more than tripled
1964-72	increased by 2/3	doubled	more than tripled
1973-75	declined in 1974	n. a.	declined in 1973-75
1976-80	increased by 18%	doubled	tripled
1981-85	declined by 15%	declined 10%	declined 20-30%

Source: Table 5-1.

---

[3] Artem'ev, Kravets, 1977, p. .

[4] Parrott, 1980, p. 87 explains the increase in the share of patent applications approved in the 1970s by the decline in the extent of duplication among applied researchers, due to the better scientific information system, and possibly, organizational changes of 1968.

The years 1981-85 witnessed a decline in the number of patents by 20-30%, caused by a 7-15% decline in the number of applications, and a 10-20% decline in the rate of acceptance. Decline in the number of patent applications in the early 1980s is paralleled by the decline in the number of rationalization proposals, and declines in other indicators of innovation in this period.[5] It can be interpreted as a result of the relaxation of pressure to patent (and to do many other things) in the last years of the Brezhnev regime.

5.2 Changes in the weight of an average invention.

When the output targets for rolled metal are set in tons, only the heaviest varieties are produced. When output is planned in rubles, as for garments, only the most expensive models are produced. To reach the target that fixes one parameter of activity, all other parameters are sacrificed. It is no surprise then, that given a target for the number of inventions, organizations will try to fill it with the most trivial solutions possible. And an increasing number of inventions will be achieved by increasingly diluting the quality of an average invention. Below, we present two sorts of evidence on the declining importance of an average invention: expert opinions and economic data.

---

[5] See Kontorovich, 1985, Chapter 8, and especially 8.9.1.

5.2.1 Qualitative evidence.

A journal conducting a discussion of inventive activity received so many letters on inventions becoming progressively less important, that it took this as a commonly accepted point of view. The cause of this practice was attributed to evaluation of the enterprises and organizations by the number of patent applications and patents.[6]

"There arise a multitude of small and microscopic improvements in the process of adapting the existing (abroad) technology to domestic conditions (raw materials, equipment). These improvements form "the muddy wave" of applications, and their constant pressure on patent experts lead to a decline of the level of all inventions, which is now commonly recognized."[7]

The chairman of a body of experts (Supervising council - Kontrol'nyi sovet) overseeing the work of the State committee for inventions, and head of one the departments of this body, state that standards used in patenting are too lax. They claim that the huge increase in the number of patented inventions in the last 10-20 years has not been caused just by the increase in creativity (hinting at the relaxation of standards as another cause). Patenting became easier than publishing an article. Random checks by the Supervising council of new patents frequently result in the reversal of patenting decisions (7 out of 13 and

[6]"V vikhre ...", 1982, p. 38-9. See also Glavatskii, 1982, p. 25.

[7]Kolesnikov and Starovit, 1984, p. 127.

5 out of 8 in the examples cited). Since this reveals lax standards for granting patents, the State committee forcefully resists such checks.[8]

5.2.2 Economic effect of implemented inventions.

The economic effect denotes savings from implementation of an invention. Firms using an invention for the first five years after it was patented are obligated to calculate its economic effect and report it to the State committee for inventions.[9]

The magnitude of the economic effect of implemented inventions is used to determine the size of the inventor's royalties, and bonuses for help in implementing the invention. The royalties are paid to the inventor during the first five years of utilization of the invention, in an amount equal to 2% of the annual economic effect of its nationwide implementation.[10] Bonuses for helping in implementing the invention are determined as 1.5% of the economic impact of hte first year, or 0.4% for ministry employees.[11] As a consequence of this, certain parties are interested in inflating the reported economic effect, as is the case with other calculations of economic effect (for new

[8]Krainev and Khostikov, 1986.

[9]Calculation of economic effect is analyzed in Kontorovich, 1985, Chapter 8 (sections 8.4.1.2, 8.4.2, 8.4.3) and Appendix T.2. This section borrows a few paragraphs from Kontorovich, 1985, 8.5.2.

[10]Sbornik, 1983, p. 42.

[11]Sbornik, 1983, pp. 50-1.

technology being developed by R&D organizations, or for new technology implemented by the enterprisees). Bonuses for help in implementation serve as a sweetener to management, and incline them to overreport the effect. As in the case of the new-technology measures in gene- ral, the possibility of inflating the effect is created by lack of integration of the plan for implementing inventions with other plans. The savings due to implementation do not have to enter the plans for profit, costs, etc. or the enterprise's accounting system.[12]

Economic-effect data for inventions are less inflated than other such measures, because the recipient of the reward, and those who calculate and report the economic effect, are often different actors with opposing interests. The inventor's royalties are paid to one or a few individuals, who may not be a part of the given enterprise's management, or who may even work elsewhere. In this case, the enterprise has no reason to inflate the effect (and the size of royalties to be paid). In fact, it tries to underestimate the effect.

At one of the largest enterprises in the country, Uralmash, the patent department calculates the economic effect of proposed inventions, to be submitted with patent applications. The rationalization and invention department, which pays royalties to the inventors, "does not trust these calculations", and performs its own, apparently lowering the initial estimates.[13] This clash

[12]Glavatskii, 1982, p. 26.

[13]"V vikhre ..", 1982, pp. 56-7.

of interests is one of the reasons for inventors to include enterprise management as fictitious co-authors on the applications for inventor's certificates.[14]

The State Committee for Inventions can check the calculations on its own initiative or at the request of the inventor.[15] The provision for the inventor's request for recalculation appears to be a reflection of the conflict over the numbers described above. One gimmick to which enterprises resort is declaring an invention to have no calculable economic effect; then, the royalties are calculated differently, and are smaller than otherwise.[16] The enterprise which implements an invention bears the burden of developing it, debugging, etc. Bonuses for helping in implementation are small (and only for the first year of implementation).[17] Still, it is not clear to me why the enterprises are so averse to paying royalties to the inventors.[18]

Published data do not allow us to derive the average economic effect per implementation. However, such data are available from another source for 1964-73 (see Table 5-3). They show a decline in the average savings per implementation in 1968-74 after an increase in 1964-67. This decline coincides in time

---

[14]For the other reasons to include managers as co-authors, see Dudkin and Shimanovich, 1980, p. 88.

[15]Sbornik, 1983, p. 42.

[16]Voronov, 1984, p. 136.

[17]Voronov, 1984, p. 136.

[18]Additional evidence on conflicts around invetors' royalties can be found in 9.2 below.

with an increase in the rate of acceptance of patent applications, and suggests that the latter means a relaxation of patenting standards. The caliber of an invention has been progressively lessened.

Table 5-3. Average economic effect per implemented invention, rubles.

1964	56,960
1965	50,884
1966	80,629
1967	63,510
1968	39,894
1969	34,310
1970	31,805
1971	31,040
1972	28,537
1973	30,457
1974	34,252

Source: Artem'ev and Kravets, 1977, p. 41.

In 1982, the economic effect from all implemented inventions declined by 1.2%.[19] The official explanation is that in the past, there were large inventions, yielding great savings. Two or three inventions could make a difference. Later, the "whales" of invention became rare, and the mass of other inventions does not yield large savings.[20]

In the Ministries of Chemical Industry, Petrochemicals, Ferrous Metallurgy, Non-ferrous Metallurgy, and Construction Materials Industry, the average economic effect of an implemented invention declined sharply from 1981-1984 (in the Ministry of

---

[19]NKh-83, 99.

[20]This is the analysis of preasidium of the Central council of All-Union Society of Inventors and Rationalizers ("Trevozhnye ..., 1986, p. 11).

Construction Materials Industry, by factor of 1.6).[21]

Enterprises prefer to implement simpler, cheaper, and less significant inventions.[22] Therefore, data on the average economic effect per implementation reflect not only the quality of inventions, but also the selction made out of the total pool of inventions by production units.

5.3 Conclusion.

The number of patents granted in 1956-80 increased more than 30 times. However, there is abundant evidence that the more than six-fold increase in 1967-1980 has been achieved in part through a dilution of the quality (weight, importance) of an average invention. After 1980, the number of patents declined in absolute terms, without any indication of the increasing weight of an average invention.

---

[21] Obukhov, 1986.

[22] Minin, 1976, p. 8.

Chapter 6. Other Measures of Output.

This chapter discusses several measures of R&D output which, for various reasons, are not as useful as the two measures analyzed in the preceding Chapters.

6.1 Publications.

Publications serve as a standard measure of scientific output, much more universal than the two measures considered in the preceding chapters. As Table 6-1 shows, the number of titles of scientific books published in 1950-65 doubled. At the same time, R&D employment and the number of science workers more than tripled.

Table 6-1. Scientific books and brochures published.

Year	1950	1958	1960	1962	1964	1965
Titles, thous.	24.7	38.5	43.6	54.0	48.7	50.0

Source: Dobrov et al., 1969, pp. 105.

After 1965, book publications continued to lag behind the growth in number of researchers. This is obvious for the technical sciences, where the number of titles published annualy hardly increased in 1965-78 (see Table 6-2), while the number of science workers in the technical sciences more than doubled in 1965-74. The number of science workers in mathematics and the natural sciences increased by 83% in 1965-74, while the number of titles, by only 40% over a longer period. This trend does not in

itself reflect a decline in productivity. Rather, it may be due to the worldwide shift of scientific publishing from books to periodicals.[23]

Table 6-2. Scientific and technical books, by discipline.

	1964	1978	growth
	number of	titles	rate, %
mathematics & natural sciences	7067	9946	41
technology, industry, & related areas	27021	27935	3

Source: Parrott, 1981, p. 16, quoting Pechat' SSSR v 1978 godu, Moscow: Statistika, 1979, p. 25.

Virtually all the growth in the number of journals seems to have occurred in the Academies. Between 1961 and 1976, the Academies started 109 new journals (73 in 1961-1970; 14 in 1971-1976). This, however, happened at the expense of irregular serials that were published by individual institutes and were shut down when the journals began publication (about 400 serials for 82 journals started by the Union academy). The number of journals published by the ministries remained virtually unchanged. The size of 300 journals was reduced in 1979, ostensibly on the temporary basis.[24] The data on periodicals indicate a decline in published output per unit of R&D input, as do data on books.

A survey of 30 institutes of the Ukrainian academy found that the average number of papers published per science worker declined by 1.1% per annum in 1966-76, and the number of monogr-

[23]Dobrov et al., 1969, p. 105.

[24]See Parrott, 1981, pp. 19-22.

aphs, by 0.5% per year.[25]

However, publications data should be interpreted with care. There is a conscious policy on the part of authorities to limit the number and length of scientific publications, with the ostensible purpose of conserving paper. It is this policy that limits growth of the number of periodicals. As part of this policy, the average length of scientific books declined in the mid-1970s, after the Central Committee decree on saving paper.[26] This strong external constraint does not allow us to use publications as an indicator of R&D output. Soviet scholars may be producing a great quanitity of material, but lack outlets to publish their results. The constraint on publishing hampers scientific productivity by producing long delays in publication and dissemination of the latest results, by forcing authors to write papers that are concise to the point of being unintelligible, and by making it harder to create new schools and air unorthodox ideas.[27] The stupidity of spending tens of billions of rubles on R&D, and not providing enough space to publish the results, defies imagination.

6.2 Citations.

Based on Science Citation Index data, it was found that between 1975 and 1981, the number of articles in Soviet scien-

---

[25] Yankevich, 1982, p. 434-5.

[26] See Parrott, 1981, pp. 19-22.

[27] Ibid.

tific periodicals declined by 18.9%, while the citation rate fell by 11% (worldwide, these grew by 67% and 12%, respectively).[28] The explanation of this strange trend lies in the restrictions on publishing described above. It can also be seen that the average number of citations per article has increased. This means that papers denied publicacion because of restrictions were less important than those that got into print.

6.3 Economic effect of implemented R&D.

Central Statistical Administration annually surveys more than 1300 R&D organizations of almost 30 industrial ministries (90% of R&D organizations in these ministries). The economic effect of the implementation of R&D results of these organizations increased by 21.7% in 1979 relative to 1975, while expenditures grew 19.5%, and personnel, 9.9%.[29] Since growth of the economic effect is almost certainly inflated, it most likely was below that of expenditures.[30] The output per ruble of R&D expenditures declined.

6.4 Discoveries.

"Discovery" is defined as finding a law, property, or phenomenon of nature which radically changes the level of

---

[28] La Brie and Sessler, 1983.

[29] Pokrovskii, 1983, pp. 51-2.

[30] See Kontorovich, 1985, Chapter 8 and Appendix T.2.

knowledge.[31] Discoveries are registered in a process similar to that for inventions, and by the same organization. Authors of discoveries are rewarded, when their discoveries are registered. The amount of the reward is established by the State Committee on Inventions and Dicoveries, but cannot exceed 5000 rubles per discovery.[32]

The cumulative number of discoveries registered since 1957 (about 300 now) has been published.[33]

Table 6-3. Discoveries.

Year	Cumulative totals, year-end	Annual increment
1957-70	93	7*
1971-75	171	16*
1976-80	240	14*
1981	254	14
1982	268	14
1983	284	16
1984	299	15
1985	313	14
1986	328	15

Note: * - average annual increment. Sources: NKh-84, 108; NKh-85, 68; "Piatiletke ...", 1987.

Table 6-3 shows that the number of discoveries registered annually was practically constant in 1971-85. The lack of increase in this measure of output in the face of growing R&D inputs means declining productivity. However, the number of

---

[31]Geographical, paleontological, and archeological discoveries, discoveries of mineral deposits, and discoveries in social sciences are not covered by this definition.

[32]Sbornik, 1983, p. 18, 20, 318.

[33]Reut, 1985, makes clear that the number is cumulative.

discoveries registered annually in 1971-84 is twice as high as that in 1957-70, indicating an increase in this measure of output in the 1960s.

A shift towards more applied research and development in the 1970s and 1980s, which will be documented in Chapters 8 and 10, must be responsible for at least part of this trend.

PART III. CAUSES OF PRODUCTIVITY DECLINE: GIVING RESOURCES TO THOSE WHO CANNOT CONTROL THEIR USE.

This part deals with the interaction of a particular technological process - production of new knowledge - with different organizational environments. Some production processes run smoothly no matter what organizational forms are chosen to govern them. Railroads and steel mills can function equally well in a command economy or as capitalist enterprises in a market economy. Other production processes are extremely sensitive to their organizational milieu. For example, small private farms handle fresh berries much better than large corporate farms, or state and collective farms under socialism.

R&D is a production process sensitive to the ways in which it is organized. This sensitivity arises from uncertainties inherent in the nature of R&D: uncertainty about which projects should be undertaken and how; uncertainty about the course of ongoing projects; and uncertainty about the quality and usefulness of the results of a project. The results of R&D can be evaluated only by the users (for applied research and development) or by peers (for basic and applied research), and only very imperfectly. In the absence of evaluation and control, R&D resources are bound to be misallocated, partly simply wasted. Organizational changes of the past 35 years directed R&D resources to those who were the least able to spend them wisely. This inevitably led to a decline in productivity of resources.

Chapter 7. Bureaucratic expansionism.

All organizations have a tendency to expand. However, expansion of production firms is limited by demand for their products. If a certain production sector expands too much, the stockpiles of its output will be visible and planners will not allow further expansion. Also, growth of production sectors is limited by scarce inputs that are centrally allocated. Expansion of the administrative apparatus is constrained by the arbitrary orders of the Ministry of Finance, mentioned above. Expansion of the R&D sector was not similarly constrained for most of the period we are studying. Unlike the administrative apparatus, regarded as a necessary evil, R&D organizations were considered to be good for the economy, providing the key to technological progress. Unlike production plants, the excessive output of R&D was not readily visible. And R&D organizations in most cases did not require any scarce resources.

The natural desire for empire-building and weak controls would have sufficed to explain the expansion drive of R&D, but there were other factors, as well. Resources for R&D are given to ministries and academies free of charge, so it does not hurt to have more of them. These resources can later be diverted to the more important uses, production or administration (in the case of ministries; see 8.4.1). It is prestigious for a ministry to have its own R&D organizations.[1] Ministries prefer to have

[1]Beliaev and Pyshkova, 1979, p. 136; Korolev, 1984.

internal sources of supply of everything, including the results of R&D.[2] All these considerations led to the founding of new R&D establishments and the expansion of old ones, over and above what was justified by the needs of the economy. This is one of the many manifestations of the hoarding of resources in a centrally planned economy.

7.1 Expansionism at the top.

In 1957-64, regional economic councils established insitutes for the sake of prestige, without paying proper attention to their quality and ability to solve problems.[3] Ministries in this period also had significant leeway in establishing R&D organizations. To constraint such behavior, in the mid-1960s permission of GKNT became necessary to found a new organizations. But this did not prevent 1,100 new institutes from opening in the late 1960s and 1970s. Lack of appropriate resources did not stop the ministries. They prefer a poorly equiped institute to no institute at all. The decision to establish an institution can be taken before there is pesonnel and equipment. Such poorly equipped R&D organizations are thinly disguised extensions of the ministerial apparatus (see 8.4.1.1).[4] It is noteworthy that in the early 1970s high-level experts already clearly understood

[2] Struminskii, 1984.

[3] Beliaev and Pyshkova, 1979, p. 136.

[4] Korolev, 1984.

that expansionism is counterproductive and has to be stopped: ".. the period of creating new scientific organizations in our country is mostly over. ... creation of new research institutes in the future will take place only in exceptional cases, as a rule, on the basis of existing divisions, laboratories, and experimental stations .."[5] However, the institutional power of the ministries proved stronger.

The constraint on expansionism was tightened in 1981. The decree of the Council of Ministers noted that the number of design, project, and research organizations was increasing in excess of justifiable need, along with other administrative and cultural organizations. The decree ordered that the number of people employed be cut in 1982-85 below the 1980 level. Ministries and other bodies were ordered to review the existing network of organizations to eliminate wasteful duplication. New research, project, design, and technological organizations can be established by permission of the Council of ministers at the request of GKNT or Gosstroi. Union ministries (committees, other bodies) and republican councils of ministers initiate the procedure, and submit proposals to GKNT or Gosstroi.[6]

While the cuts mandated by this decree never materialized, there has been a two-year lull in the growth of R&D employment (see Table 1-1), accompanied by some restructuring. In the early 1980s, 145 institutes were closed and several dozen were merged

---

[5]Gvishiani, 1973, p. 156.

[6]Bogoliubov and Smirtiukov, 1983, p. 198.

with others. The main obstacle to closing down institutes was the ministries' objection that there would be no one to serve the R&D needs of their sector.[7]

Expansionism derives added strength from the fact that it is exceedingly hard to close down an existing organization, a phenomenon well known to students of bureaucracies around the world. "... the cases when unpromising laboratories or institutes are closed are exceedingly rare."[8] "It is easier to open a new affiliate of an institute than to properly equip an existing one. In such conditions, some institutes get inflated, suffer from proliferation of topics, endlessly duplicate each other's work".[9] " ..reorganization includes mostly the establishment of new institutes, centers, and other structural units, rather than closing some departments or even institutes to open the new ones."[10]

Expansionism is not the exclusive property of sectoral R&D. Exessive expansion of higher education is now officially acknowledged.[11] Academies also tend to expand as much as possible. "Even in SOAN, there is still a trend to increase the number of organizations, and this harms any serious effort. Given the number of specialists, increasing the number of organizations

---

[7]Korolev, 1984.

[8]Chemodanov, 1978, p. 71.

[9]Struminskii, 1984.

[10]Bachurin, 1985, pp.89-90.

[11]"Osnovnye napravleniia perestroiki ...", 1986.

also increases the number of people who manage, and decreases the number of people who work."[12]

7.2 Expansionism at the bottom.

Ministries, academies, and local authorities are not the only parties responsible for the expansion of R&D unrelated to any real need. R&D establishments themselves are among the chief perpetrators. Directors of R&D organizations are "empire-builders" in their own right. They have three potent organizational incentives for doing so: planning from the achieved level, evaluation of the institute's performance by its expenditures, and classification of institutes by category, which makes managerial salaries a function of the size of their institutes.

The current level of employment and expenditures of an institute serves as a benchmark for the future, to be at least maintained. This is true not only for regular projects, but for any extras that are included in the plan. Employment grows "automatically", *since the funds and personnel received* for performing additional work for GKNT is later counted as the "base" level.[13] It is still rare for projects' funding to terminate as the projects end, without being added to the permanent "base" budget of the institution.[14]

Organizations and individuals are evaluated by the "volume

---

[12] Nesterikhin, 1985.

[13] Bogaev and Savel'ev, 1982, pp. 57-8.

[14] Lebedev, 1976, p. 66.

of work performed", which, in turn, is measured by resources expended (see 3.5.2). Therefore, managers of R&D organizations are interested in maximizing their financing from the budget, personnel limits, and contract work. Contract work stimulates personnel inflation still further, for the money it brings cannot be used to increase the salaries of existing personnel.[15]

Institutions are not interested in cutting R&D expenditures, because this will ultimately depress the wage fund and the number of employed, which in turn determine the category of the institute and the salary leve of its management.[16] Awarding R&D organizations categories according to the number of employees fuels expansionism, since salaries of the managers increase accordingly.[17]

As with other manifestations of expansionism, these ones are not restricted to the sectoral R&D. There is ample evidence that they also apply to the academic institutes.[18] Union Academy found a way to increase its personnel in contracts that allow the customer to transfer his labor limits to the contractor. This resulted in 1.2% increase in its personnel (from 1970-82?).[19]

---

[15]Bogaev and Savel'ev, 1982, pp. 57-8.

[16]Dzhanoian, 1986.

[17]Zavlin, et al., 1973, p. 5.

[18]Bogaev and Savel'ev (1982) are extremely concerned with "personnel inflation" in the institutes of the Ukrainian Academy, and suggest drastic meausres to curb it.

[19]Bliokov, 1984, p. 38.

Chapter 8. Increasing share of sectoral R&D.

At the outset of the explosive growth of R&D in the 1950s, a momentous decision was made: to channel R&D resources primarily to branch ministries. This decision shaped the current R&D sector and influenced its productivity and other characteristics. In this chapter, we explore the motives of this decision, and provide quantitative data on the growth of the share of sectoral R&D in the national total. We then analyze the organizational characteristics of R&D and of branch ministries, and bring out the major points of conflict between the successful management of R&D and the interests of the ministry. The performance of R&D under the branch ministries is analyzed last.

8.1 Trends in the shares of resources of the three systems of R&D.

The number of science workers is used here as a proxy for resource allocation among the three systems of R&D. The shares of the three systems were stable in the early 1950s, with higher learning institutions employing more than half, and sectoral R&D, less than 40% of the total (see table 8-1). The change in the structure of national R&D came during the great expansion of the sector in the late 1950s-early 1960s. All systems grew in this expansion, but at a vastly disparate pace. As a result, in just 6 years, the shares of higher learning institutions and sectoral R&D were reversed. The share of the academies initially in-

creased, but then declined after 1963, as institutes of the Division of Technical Sciences were transferred to sectoral ministries. The shares of the two systems established in 1963 are still prevalent today: 58% in sectoral R&D, 35% in higher learning institutions, and 7% split equally between the Union and republican academies. The long-run trend in the allocation of resources can be summarized as a large increase for sectoral R&D, at the expense of a large loss for higher learning institutions, and some decline in the share of the academies.

The increase in the sectoral R&D's share of science workers is partly due to a change in the definition of this concept in 1962, when persons systematically engaging in research at non-science establishments (enterprises, design and project-making organizations) were first included.[20] The share of science workers in non-science organizations of sectoral R&D increased fourfold in 1962 (see table 8-2), and the share of sectoral R&D in the total jumped by 6 percentage points. However, barring this single instance, most of the gain came in the "science" subsector of science and science services sector: the founding of new NII, the expansion of the existing ones, and the incoporation of former Academy institutes.

Table 8-2 misses the trend of the 1970s and 1980s: the shift of personnel from independent organizations to constituent parts of production and science-production associations. The share of research and technical personnel in sectoral NII fell from 52.3%

[20] NKh-63, 712.

Table 8-1. Science workers in three systems of R&D, shares, %.

Year	Academies Union & Republican	Higher learning institutions	Sectors
1950	9.23	53.23	37.54
1953		54.92	
1954		54.33	
1955	9.14	53.19	37.67
1956	9.20	52.09	38.71
1957		50.57	
1958		47.78	
1959	12.76	44.45	42.79
1960		41.48	
1961	10.12	39.20	50.68
1962		34.22	
1963	7.86	34.77	57.37
1964	7.71	33.71	58.58
1965	7.84	33.37	58.79
1966	7.91		
1967	7.85		
1968	7.97		
1969	7.93		
1970	7.68	37.62	54.70
1971	7.54		
1972	7.49		
1973	7.37	28	64.63
1974	7.17		
1975	7.13	34.97	57.90
1976	7.05		
1977	7.04		
1978	7.04		
1979	6.97		
1980	7.06		
1981	7.05		
1982	6.98		
1983	7.05		
1984	7.10	35	67.90
1985	7.27		

Source: NKh. Total academies in 1950 - Chemodanov, 1978, p. 58.

Table 8-2. Science workers in sectoral R&D as a share of all science workers, %.

Year	Total	Sectoral Academies	R&D organizations	Enterprises & administration	Enterprises
1950	37.54		34.15*	3.38	
1953				3.39	
1954				3.47	
1955	37.67		33.96*	3.71	
1956	38.71		35.16*	3.53	
1957				2.98	
1958				2.58	
1959	42.79	6.08	34.32	2.39	1.7
1960			39.64	2.02	
1961	50.68	3.22	45.67	1.79	
1962				8.77	
1963	57.37	1.63	48.25	7.48	
1964	58.58	1.55	49.03	8.00	
1965	58.79	1.42	49.49	7.88	6.0
1966		1.28			
1967		1.22			
1968		1.19			
1969		1.28			
1970	54.70	1.58			
1971		1.47			4.0
1972		1.47			
1973	64.63	1.43	57.00	4.00	
1974		1.42			
1975	57.90	1.50			
1976		1.54			
1977		1.69			
1978		1.65			
1979		2.08			
1980		2.11			
1981		2.07			
1982		2.02			
1983		1.96			
1984		1.97			
1985		1.96			

Note: * - including sectoral academies. Source: 1973 - Table 8-8; enterprises: 1965 -Lebedev et al., 1970, p. 38; 1959 - Gatovsky, 1971, p. 163; 1971 - Kanygin, et al., 1972, p. 44, quoting <u>Pravda</u>, Feb. 4, 1972; 1985 - Kushlin, 1986, p. 217.

of the total in 1966 to 39.4% in 1976, while the share of those employed at the enterprises (i. e., PO and NPO) increased from 9.3% to 22.1%.[21] However, since most NII have retained their independence after mergers into associations, it is still fair to say that sectoral NII emerged in the early 1960s as the main type of R&D organization and remains so today.

Data on science workers do not fully reflect the current relative position of each of the three R&D systems. Distribution of expenditures gives a better idea of the size of sectoral R&D (see Table 8-3).

Table 8-3. Expenditures by sector of R&D, shares, %%.

	a	early 70s b	1973 c
Sectors of the economy	83	82	82
NII, their filials, experimental-testing production establishments, bases, labs, stations, etc.		80	78
NII and filials		60	58
Production enterprises and organizations		2	4
Academies	8	8	8
VUZy and other teaching institutions	9	9*	9*
Museums, theaters, libraries		1	1

a: Kozhevnikova and Shchedrina, 1976, p. 158; b: Kanygin and Danilovtsev, 1976, pp. 135-6; c: Shcherbakov, 1982, pp. 29-30.
* - and their laboratories.

Sectoral R&D consumes four fifths of all R&D funds, dwarfing

---

[21] Bliakhman and Mintairov, 1981, p. 60. Research and technical personnel includes science workers and those other R&D employees who have special education. ibid., p. 55.

the other two systems. Comparing Tables 8-1 and 8-3, we can see that expenditures per science worker are the highest in sectoral research, followed by the academies (their shares of total expenditures are higher than the shares of science workers). The share of total R&D expenditures allocated to the institutions of higher learning is much lower than their share of science workers.[22]

8.2 Why sectoral R&D was given priority.

The strategic decision to give priority to independent R&D institutions under sectoral ministries was motivated by the desire to derive the largest benefit out of R&D, and in particular, to make maximum use of R&D results in production. Science had to be positioned closer to production, to become more responsive to the production's needs, and to facilitate transfer of R&D results to the plants. This meant subordinating applied research and development in a particular sector to the same organ that is responsible for production, i. e., the sectoral ministry.[23] This is a perfectly sound solution to the problem posed, given the difficulties of inter-ministerial coordination.

It also made sense to develop independent specialized R&D institutions within ministries. Such institutions, being sub-

[22]The share of science workers overstates the role of R&D in teaching institutions, because many of those counted do not do research. The share of expenditures understates this role, because part of research is financed out of the education, not the R&D budget. See 14.1 and Appendices A.2 and A.4 below.

[23]See 3.2.2 on organization of R&D in a sector of the economy.

ordinated to the ministry or a glavk, would serve many enterprises in the whole sector or a subsector. If the institution were subordinated to the enterprise management, it would serve only the latter. The ministries are charged with long-run technological policy in their sectors, and R&D institutions are supposed to help develop and realize such a policy.

8.3 Objectives of ministries and utilization of R&D resources.

Ministries are driven largely by the same incentives as production enterprises. They are responsible for meeting short-run production targets. Ministries are largely independent of the customers, since their performance is evaluated by their superiors (Council of Ministers, Central Committee). Therefore, ministries can sacrifice the interests of customers (e. g., compromise the quality and durability of output, increase prices, or produce obsolete or unneeded goods). Ministries also tend to create autarchic systems of supply, because cooperation with other ministries proves to be costly and unreliable. They tend to neglect any concerns above and beyond their narrowly defined responsibilities, to the detriment of national goals and overall efficiency (so called "departmentalism"). Ministries obtain their resources for free, and therefore are always interested in getting more, but not necessarily in better utilizing what they have.[24]

---

[24]On ministries, their incentives, and innovation, see Rassokhin, 1985, pp. 31-47, and chapter 2. Scathing criticism of the ministries can be found in the speeches at the 27th party

Sectoral R&D establishments work mainly for the enterprises of their own ministries. Theoretically, they are subject to the control of their immediate users - enterprises, and the ministry itself. (The influence of enterprises of other ministries is much smaller, and can be disregarded here.) Production enterprises fail to exercise effective control over R&D organizations for two reasons. First, there is no particular pressure to innovate to cut costs or provide new products for customers. Production enterprises are interested in innovations that make their work easier, e. g., ones that free them from reliance on hard-to-get inputs, or make production process more reliable and predictable. They would accept innovations that save current costs without major overhaul of existing structure.[25] Lack of interest in technological progress means lack of interest in the quality of output produced by the R&D sector. (This, again, should be qualified; no one wants to work with faulty, unintelligible designs.)

Second, even when the enterprises are interested in innovations, they have little leverage over the R&D institutions. The latter are evaluated by their superiors, not customers; they are budget- rather than revenue-based, and do not depend on the good will of customers for their survival.[26] (Though there are

---

congress, Pravda, February 26 - March 8, 1986.

[25]"Tekhnologicheskii ...", 1986, p. 49.

[26]Financing sectoral R&D through contracts with enterprises does not always change this situation; see 3.5.3 above on choise of projects. Also Berliner, 1983, p. 370.

customers that are interested in the output of R&D, and do have leverage over its providers: the military and the top leadership of the country.)

This leaves only one body to effectively control and direct sectoral R&D: ministerial departments.[27] The general problems of evaluating performance by a remote bureacratic body combine with the specific nature of R&D to make it ungovernable. "Management of sectoral science by ministries and main administrations increasingly degenerates into mere registration of the accomplished facts. Supervising organizations lack expertise to do anything else. Instead, they issue rules and regulations prescribing in detail how R&D should be planned and financed; reporting, incentives, and controls."[28]

In subsequent sections, we will show how the objectives of the ministries give rise to misuse of R&D resources. Since current production has the highest priority, R&D resources are diverted to it. Research is reoriented to the most immediate, often trivial needs. Since R&D resources come free, ministries try to obtain as much as possible, without concern for their utilization. In the situation when customers are indifferent, and bosses, indifferent and/or incompetent, it is easy for R&D organizations to fake performance. The reasonable goal of posi-

---

[27]Review by highly qualified peers and scientific ethics, important for control over the use of resources in the Academy, are largely absent in sectoral R&D.

[28]Lebedev, 1986, p. 89.

tioning R&D closer to production, in combination with the organization of the production sectors, leads to these unintended consequences.

8.4 What ministries actually have done with R&D resources.

This section describes different ways in which sectoral ministries lower the productivity of R&D organizations under their control.

8.4.1 Diversion of resources to non-R&D uses.

Resources earmarked for R&D purposes in sectors of the economy are planned and allocated separately from those destined for other purposes. However, once the sectoral ministries obtain resources, they can reallocate them to uses that have higher priority for them. Here, we document diversion of R&D resources to administrative and current production needs.

8.4.1.1 Extension of the administrative apparatus under the guise of R&D.

Administrative positions in the ministries are constantly cut according to arbitrary targets established by the Ministry of Finance. To keep the workload of its own employees from rising as a result of these cuts, ministries shift part of their work to R&D organizations.[29] (Even without arbitrary staff cuts, ministries would be tempted to shift part of their work elsewhere to

---

[29]Sominskii, 1986, p.15.

lighten their own load, since R&D organizations are perceived as largely useless for the ministry's purposes.) Sectoral institutes become extensions of ministry apparatus, in Gor-bachev's words.[30]

Here is the list of administrative functions thrust upon sectoral organizations:

- preparing drafts of reports for superiors, procuring supplies, organizing repair of factory equipment;[31]
- developing forecasts of technology, five-year and other plans and programs; developing and implementing sectoral norms and standards, developing draft state standards; checking adherence to and improving existing production technology; coordinating and controlling the innovation process; helping with implementing their results in production (giving technical, methodological and organizational help to the firms; this may be included in plan for development work); conducting reliability studies; developing normative information, manuals, technico-economic studies to improve planning and management within their sector.[32]

Sectoral NII review and approve technological documentation (designs, etc.) for their subsector. E. g., a plant that is going to produce consumer goods as a side line must get all

---

30"Politicheskii ...", 1986.

31Rassokhin, 1980, p. 55.

32Bekleshov, et al., 1986, pp. 39, 45, 71.

designs approved at the corresponding consumer-goods NII.[33] The use of certain parts, materials, and devices in the newly designed products has to be approved by the sector producing these items; the functions of approval are frequently carried out by sectoral institutes.[34]

In one sectoral plan of R&D, 15-20% of technical and technological projects, and 40-50% projects in economics, would have been properly regarded as the responsibility of ministries or central planning organs.[35] In technological institutes of the Ministry of Heavy Machinebuilding, only 70-80% of personnel are engaged developing technological processes and design of special equipment for the needs of the ministry. The rest are occupied by technical-economic problems: analysis of current production, compilation of plans, forecasting and planning of technological progress in the sector, resource savings, improvements in management, etc.[36] (See also Table 8-4).

Many of the administrative tasks listed above arose only in the 1960s and 1970s, with attempts to institute better planning and management system for the economy and technological progress in particular.

---

[33] Motorin, 1979.

[34] Obtaining approval for use of a standard bearing in a piece of newly designed equipment requires presenting six documents to the All-Union research institute of bearings for approval. Use of mixers has to be approved by the research institute for chemical machinery. Bykov, 1981, p. 68.

[35] Sominskii, 1986, p. 15.

[36] Berliner, 1982, pp. 95, 98; see also Cherniak, 1985, p. 2.

Table 8-4. Distribution of sectoral NII and KB by the main direction of their work, shares of the total number of institutions in the sector, %%.

Ministry	Product innovation	Process innovation	Organization of production, economic research, information
Machine tools & tools	72	21	7
Chemical & petroleum machinebuilding	78	16	6
Machinebuilding for light and foodprocessing industries	86	7	7
Machinebuilding for heavy, power generation industries and transport	52	24	24
Chemical industry	50	42	8

Source: Grinchel', 1974, p. 61.

Development of computerized management information systems (ASU) for enterprises and ministries is one of the glaring examples of diversion of R&D resources. This massive task involved hundreds of thousands of people in the 1970, many of them in sectoral R&D institutes.[37] The nature of the task is routine programming, that would have been done in the US by a software firm, or by an MIS department of the business firm for internal use.

8.4.1.2 Diversion of investment resources and capacities intended for experimental facilities.

Meeting output targets is the first responsibility of the ministries. Output targets are taut, as a rule: it is hard to

[37] See Agursky, 1976, p. 37-8 on NIITM.

reach them, given the availability of inputs. Development of R&D results requires extensive facilities for testing and manufacturing models and prototypes. But this is a task of lower importance for the ministries. Therefore, the ministries regularly divert resources from testing and pilot production facilities to regular production capacities, to the detriment of R&D productivity.

This diversion takes three main forms. First, testing and pilot production facilities have low priority in the allocation of investment funds. In industry, less than 1% of total investment is directed to construction of testing and experimental facilities, and in 41 ministry, this figure is 0.3% of total investment. This proportion is considered to be far too low for modern industry.[38]

Second, the investment funds that are allocated to testing and pilot production projects do not command real investment resources to the same degree as funds allocated for the creation of production capacities. Construction plans for experimental facilities are regularly underfulfilled by more than average margins.[39] Practically every year, machinebuilding ministries fail to use all the investment funds allocated to experimental production facilities.[40]

---

[38]Anchishkin, 1986, p. 12; also, Rassokhin, 1985, p. 93; Glagoleva, 1983.

[39]*Ibid.*

[40]Lyskov, 1982, p. 141.

Finally, the existing experimental and testing facilities are used mostly for boosting series production, despite explicit prohibition from doing so.[41]

In machinebuilding in the 1970s, small series production constituted 30-40% of the output of experimental plants. In the chemical industry, the share of small series production increased by 7% per annum in 1968-1978, while the share of experimental work according to the topics of research organizations was declining by 4% a year.[42] In the instruments and computer industry, experimental production units of R&D organizations had 40% of their capacity burdened by extraneous work in 1975, and this share increased at the rate of 1-2.5% a year.[43]

Not all of this is the ministries' fault. Experimental production plants that are independent entities are interested in increasing series production.[44] They are reluctant to transfer some products, particularly those that are expensive and in short supply, to the regular series production plants. They prefer to manufacture small series of these products themselves. Small series production favorably influences the size of the bonus

---

[41] Rassokhin, 1984, p. 56, 97.

[42] Bliakhman and Mintairov, 1981, p. 92.

[43] Tverdokhleb and Bialik, 1984, p. 53, quoting M. L. Bashin. Novaia tekhnika i opytnye predpriiatiia. Moscow: Mashinostroenie, 1979.

[44] This does not apply to experimental production shops within R&D organizations.

fund.[45] Planning procedures equate experimental production facilities with series and small series production plants, stressing the quantity of output, and disallowing capacity reserves for fast response to the needs of R&D.[46]

Because of the irregularity of orders for experimental production, some series production may well be efficient in these facilites.[47] But in the conditions of a general shortage of experimental production capacity, this is not so.

The result has been a large number of institutions producing only paper: designs of machines and processes that have never been tested. About half of R&D organizations, and a similar proportion of machinebuilding plants, have their experimental production facilities. In the early 1970s, in machinebuilding, 20% of research institutes did not have appropriate facilities. Only 30% of independent design bureaus had their experimental production facilities.[48] And it should be remembered that these facilites were increasingly burdened by routine production. Cooperation in the use of such facilities among different R&D organizations has not been developed. According to some estimates, 20% of R&D results are not used because of lack of

---

[45]Bliakhman and Mintairov, 1981, p. 92; Tverdokhleb and Bialik, 1984, p. 54.

[46]Kiselev, 1986, p. 30.

[47]Tverdokhleb and Bialik, 1984.

[48]Kushlin, 1976, p. 82, 83, 87.

experimental production facilities.[49]

8.4.1.3 Use of R&D personnel in physical work.

All organizations in the Soviet Union are given tasks unrelated to their direct responsibilities: sweeping the streets, harvesting, etc. These tasks come from local party committees. Ministries and enterprises have their own urgent needs, for which there are no hands available: completion of a construction project, cleaning the factory yard, or doing the twelfth hour assembly line work. Diverting production workers to such assignment would jeopardize their output plan targets. Therefore, R&D organizations and department of production enterprises receive a disproportionate share of such assignments.

Designers are used to sweep the streets and work in construction and agriculture. Designers at plants take turns working as blue collar workers, and scrub pots at the plant cafeteria.[50] Designers and researchers are the first ones to be sent to do such tasks. At one enterprise, 15% of designers' annual working time is spent on tasks unrelated to their work.[51] At another plant, 10-12% of designers' time is so spent.[52] It is estimated that up to a half of designers perform work unrelated

---

[49]Glagoleva, 1983.

[50]"Tema ...", 1985, p. 129.

[51]Kostin, 1983, pp. 26-7.

[52]Pushkarev, 1986, p. 114.

to design.[53]

Part of the resources counted as inputs into R&D are actually used for other purposes. This depresses the productivity of R&D, as we measure it.

8.4.2 Misdirection of R&D effort.

In addition to diverting R&D resources to other uses, ministries influence the kinds of projects undertaken in R&D, and the outputs produced.

8.4.2.1 Increase in the share of development and of minor projects.

Ministries are not interested in radical innovations, because they disrupt the flow of current production. They are interested in minor improvements in existing technologies that would make them more reliable without disruption of production schedules. Therefore, ministries orient R&D towards increasingly more applied research, away from research to development, and to increasingly less important projects. Changes in planning and organization of sectoral R&D, described in chapter 8, are also responsible for these results.

The institutes of the Division of Technical sciences of the Academy, which were transferred to the ministries in 1961 and 1963, were reoriented from the problems useful to several sectors to the narrow needs of their particular sector. The depth

[53]Bykov, 1981, pp. 67-71.

and quality of their work also suffered.[54]

The share of mission-oriented research in the total R&D effort of machinebuilding declined by a factor of 3 from 1973-82.[55] According to the studies of GKNT, projects oriented to the creation of the next generation of technology ("prospective", as opposed to "current") comprise 8-10% of projects of head institutes.[56] In the late 1970s, the share of projects carried out according to the State plan of the USSR (presumably, the most important projects) in the total number of R&D projects declined.[57]

On the other hand, in the Ministry of Instruments and Computers, the share of research projects fell insignificantly over the 1970s, and the share of development projects increased correspondingly (see Table 8-5). This is explained by better

Table 8-5. Share of research projects in the total volume of projects in Minpribor, %.

	1970	1975	1980	1985
Research	23.0	22.5	22.0	21.0
On own initiative	5	3	4	5
Development	70	73	72	72
Other	2	1.5	2	2

Source: Bekleshov, 1986, p. 46.

organization, which allows the results of research projects to be

[54] Rassokhin, 1985, pp.

[55] *Pravda*, May 28, 1983, editorial, quoted in Rassokhin, 1985, p. 220.

[56] Lyskov, 1982, p. 140.

[57] Pokrovskii, 1983, p. 187.

used in a series of development projects.[58]

Industry prefers smaller innovations with a shorter payoff period. This leads to an increase in the number of projects, which become shorter and more routine.[59] "... the number and size of the projects increase, infrequently at the expense of small and insignificant topics, often duplicating. What is needed is rather the deepening of R&D with concentration of resources on large topics, on developments that would bring large yields."[60] The number of projects in the institutes of many ministries is increasing year after year.[61] The share of short-term projects has been increasing in the institutes of the Ministry of Machinebuilding for Light and Foodprocessing industries.[62] The research institute of photography and cinematography is working on 180 projects simultaneously. The time of completion of a project has been cut there from 5 to 3 years.[63]

A survey of about 150 NII in construction found that they devote only an insignificant portion of their time to their direct duties. Ministries burden them with making standard,

---

[58]Bekleshov, 1986, p. 46.

[59]"Politicheskii ...", 1986.

[60]Gatovskii, 1971, p. 130.

[61]Leont'eva, 1986.

[62]Zavlin and Iudelevich, 1985, p. 93, quoting Pravda, June 23, 1983.

[63]Kozhanov, 1986.

run-of-the-mill designs, and other inappropriate tasks.[64]

8.4.2.2 Creating R&D organizations in the sectors without a scientific basis.

Some sectors have no scientific base for their technology. R&D can do little for these sectors, and should not be funded (see Chapter 2). Yet these sectors have their ministries, which want to have R&D organizations out of prestige considerations. Among the sectors listed in Table 8-6, supply, trade and procurement, and municipal services lack a scientific base.

Table 8-6. Average annual R&D employment by sector, index, 1969 = 1.

	1970	1971	1972	1973	1974	1975
Industry	0.996	0.992	0.986	0.994	0.998	0.996
Construction	1.05	0.95	1.05	1.09	1.09	1.09
Geology	1.0	0.97	1.0	0.94	0.94	0.91
Agriculture	1.02	0.96	1.06	1.05	1.07	1.07
Forestry	1.0	1.0	1.2	1.0	1.0	1.0
Transport	1.0	1.0	1.0	1.0	1.1	1.1
Communications	0.9	0.9	0.9	0.9	0.9	0.9
Trade and procurement	1.0	1.0	1.0	1.0	1.0	1.0
Supply	1.0	1.0	1.8	1.8	1.8	1.8
Municipal services	0.7	0.7	1.0	1.0	0.7	0.7
Education	1.07	1.0	1.1	1.17	1.14	1.14
Culture	0.83	0.83	1.0	1.0	1.0	1.0
Health, welfare, sport	1.0	0.96	0.98	0.96	0.96	0.95
Academies	0.99	1.02	0.99	0.97	0.98	0.96
Other sectors	1.03	1.08	1.03	1.03	1.05	1.11

Source: Pokrovskii, 1977, p. 49.

[64] Rassokhin, 1980, p. 55.

Whatever technological progress there is in these sectors comes from the equipment developed and supplied by machinebuilding. The same is true for many sectors of industry. In market economies, there is no or very little R&D observed in these sectors, because technological opportunities are lacking. In the Soviet economy, cor responding ministries still manage to obtain funding for R&D establishments. This is where fake NII arise most frequently (see 8.4.2.3 below). Table 8-6 suggests that R&D resources in some of the sectors without scientific base (e. g., supply) have been growing faster than the average. To the degree that this is so, it will lower R&D productivity over time.[65]

The volume of R&D outlays in the sectors without scientific base can be seen from Table 8-7. The share of R&D personnel in trade, supply, procurement, and housing and municipal services is 0.9%. Some additional bogus R&D personnel is in sports and social security, which are lumped together with medicine. On the whole, the share seems to be too low to matter for the decline of R&D productivity. Of course, there are more R&D establishments within industry, transport, and other sectors with no scientific base, but we have no systematic data about them. (E. g., river transport spends millions on scientific research annually; predictably, it obtains meagre payoff.[66])

---

[65]This will also be responsible for lower R&D productivity relative to the West.

[66]"Nachalas' ...", 1986.

Table 8-7. Distribution of R&D employment and science workers by sector of economy in Moscow in 1978, shares, %.

Sector	R&D employment	Science workers
Industry	47.5	45.5
Agriculture	3.5	2.0
Transport	3.0	3.0
Communications	1.0	2.0
Construction	5.0	6.0
Trade	0.35	0.48
Supply, procurement	0.35	0.67
Health, sport, social security	7.3	4.0
Administration	6.2	7.0
Education, culture	12.5	14.6
Housing, municipal services	0.2	0.18
Academy of Sciences	13.0	14.5

Source: Riabushkin, 1985, p. 198.

8.4.2.3 Unproductive and fraudulent institutions.

Rapid expansion of sectoral R&D has drawn into the sector a mass of people who are unable and unwilling to perform real research and development. Coupled with weak control exercised by the ministries and customers, this has given rise to an entire class of establishments that are spinning yarn or engaging in fraud, faking research.

The NII for biological testing of chemical substances of the Ministry of Medical and Microbiological industries, with a staff of over 2000, spent more than 50 million rubles in the last 12 years, without producing any results. The All-Union NII for drilling technology of the Ministry of the Petroleum industry has for 30 years failed to develop improved drilling bits urgently

needed by the industry.[67] The head experimental-design institute for straw and grass processing equipment of the Ministry of Machinebuilding for livestock farming performed 4 million rubles worth of work (a two-year budget) without any practical result, while the equipment currently produced is obsolete and has not been renewed for 20 years.[68] Stories about R&D organizations that do not produce anything regularly appear in the press.[69]

In addition to unproductive establishments, there are those which engage in fraud, distort their reporting or report the same project twice or an unfinished project as completed.[70] Sectoral science, with its lack of peer review, monopoly of head institutes, and incompetent supervision from the ministry, is the most fertile ground for fraud.[71]

8.4.2.4 Monopoly of head institutes.

One of the chief official reasons for organizing the economy along sectoral lines is that sectoral ministries develop and

---

[67]Solomentsev, M. S., Pravda, March 1, 1986, p. 3.

[68]Grishkiavichus, P. P., Pravda, March 1, 1986, p. 3.

[69]See, e. g., Prokhorov, 1985; Varavka, 1986; Ryzhkov, 1986, pp. 8-9.

[70]Shalgunov, 1986.

[71]Fraud is widespread in republican academies (see Appendix 8.1), and even occurs in the Union academy. Ushanov, 1986, reports on a highly prestigious establishment, the Academy of Science physics insitute in Moscow, engaging in fraudulent research topic for a decade.

carry out a unified technological policy. for their sectors.[72] Leading sectoral institutes of the ministries are legally charged with determining the technological policy of the sector. Their statutory task is to conduct intra- and inter-departamental coordination of R&D, and monitor execution of tasks by other organizations of corresponding specialization or working on the same topic.[73] Head institutes have a monopoly position: all research, development, and implementation in the field, irrespective of where it is performed, requires their approval.[74] Thus, all work on metalworking has to be approved (soglasovan) by Experimental NII of metal-cutting machine tools of the Ministry of Machine tools (Minstankoprom).[75] The leading institutions use this monopoly position to block projects of outsiders (individuals, institutes of the Academy of sciences and of other ministries).[76] The main reason for that is to promote the institute's own solution to the problem by ignoring the competitors. Not infrequently (according to one account, typically) the

---

[72] E. g., Rassokhin , 1985, p. 51.

[73] Gvishiani, 1973, p. 97.

[74] This dates from the late 1950s - early 1960s. Beliaev and Pyshkova, 1979, p. 72.

[75] Special legal acts gave similar rights to two academic institutes in their respective areas: Paton institute of electric welding of the Ukrainina Academy and Institute of catalysis of the Siberian division of the Union Academy. Rassokhin, 1980, p. 58.

[76] See, e. g., Lyskov, 1982, p. 141; Palterovich, 1984, p. 63; Rassokhin, 1985, pp. 258-62; "Tekhnologicheskii ... ", 1986, pp. 50-1.

head institute will initially block outsiders' ideas, only to promote them later under its own name.[77] It also appears that the enterprises in a sector are often reluctant to experiment with technologies that do not originate in their head NII.[78]

The monopoly of head institutes flows naturally from the notion of a unified technological policy. Ministries do not object to such behavior on the part of their institutes because they have no need for innovations. They are in the monopoly position vis a vis the users of their output, just as the head institute is. Head institutes take on the role of advocates of their ministries' positions.[79]

The obstruction of development of outsiders' technologies does not necessarily depress measured R&D productivity. Instead of developing a better prototype following the outside idea, the head institute may develop its own, less efficient one. However, the true output of R&D is no doubt depressed by this practice.

Sectoral head insitutes are but the worst manifestation of lack of competition in Soviet R&D. The 1968 decree provides for the use of competitive R&D for important projects, but in actuality, they are not used. This is explained by the ministries' desire to monopolize an important project.[80] The large size of institutes makes it almost inevitable that there will be no more

---

[77]Rassokhin, 1984, p. 53-55.

[78]Riabov, 1986.

[79]"Politicheskii ...", 1986.

[80]Rassokhin, 1985, pp. 132-3.

than one for a sector or subsector.[81]

8.5 Conclusion: weakening of sectoral science.

The result of all these influences is a sectoral science which is not deemed strong enough to solve really important industrial problems. One reflection of this weakness is that sectors tend to bring the problems with which they are concerned not to their sectoral institutes, but to the Academy. Thus, an official from an old oil producing region stresses the economic importance of extracting more oil from existing fields, and complains that though sectoral institutes are at work on the problem, the Academy is not. He pleads for involvement of the Academy as a solution to the problem.[82] The Minister of Railroad complained that the Academy is not concerned with transport problems; there is not even a single academy member who studies railroads.[83] It should be remembered that the railroad ministry has 4 NII, 15 higher learning intitutions, and 2 experimental plants, employs 13,500 science workers, designers and technologists, including 370 doctors and 4,700 candidates of science, and spend 40 million rubles a year on R&D.[84] Producers of transport equipment have their own R&D etablishments. Reportedly, there have also been attempts to involve the Academy in improving the

[81] Sominskii, 1986, p. 18.

[82] "Rech' tovarishcha Usmanova", 1986.

[83] "Rech' tovarishcha Konareva", 1986.

[84] "Kursom ...", 1986.

technology of producing gravel for cosntruction.[85]

Dissatisfaction with sectoral R&D reached its high point in 1985-86, with unprecedentedly harsh criticism leveled at it. "Sectoral organizations infrequently are spinning their wheels, working without any results. Their work is subordinated to the defense of departmental interests, is not creative, and addresses petty subjects, with resources spread thin across a large number of insignificant projects. Ministry officials exhibit inertia and irresponsibility in the utilization of their R&D resources".[86]

---

[85]Rassokhin, 1985, p. 106.

[86]"Ob osnovnykh ...", 1986.

Chapter 9. Bureaucratization of R&D.

Parallel with increasing the volume of resources allocated to R&D, the Soviets have been trying to improve their utilization. Increasingly more complicated administrative controls have been erected. Systems for approval of designs and patents have become more elaborate; detailed standards have beeen issued on how R&D should proceed; and planning, management, and financing procedures whave become increasingly more sophisticated. This process, called here "bureaucratization", has three effects:

- an increasing share of R&D workers have been occupied with planning and managing, not actual work;
- rigid general rules and procedures have hampered R&D;
- R&D has been tied even closer to the production enterprises, which demand routine, insignificant work.

We consider first bureaucratization of design and inventive activity, and then more general organizational changes in sectoral R&D, and their effects.

9.1 Bureaucratization of design.

9.1.1 Standardization.

The number and degree of detail of standards regulating design has been increasing. The entire process of the creation of new products is now tightly regulated by state, sectoral, and enterprise standards. Many of these standards establish parame-

ters of secondary importance, such as markings, forms, etc.[1] The standards are obligatory in design. The number of standards is so large that it is impossible to follow all of them. One large enterprise receives 400-500 new and modified state standards annually. Up to 50 standards may be relevant for one product. Changes in standards force modifications in all drawings and other technical documentation in current use, which number in the millions. The revisions concern mainly the rules of presenting drawings, the text, and the legend. These formal, relatively unimportant standards are often enforced more vigorously than the more important ones. The list of state and sectoral standards, guiding technical materials, instructions, methodological instructions, statutes and informational letters of ministries, which have to be taken into account by the locomotive designers in their work, has 45 entries.[2]

"Many recently issued general purpose standards, regulating the organization of development, are too general, intended for the whole economy or whole industry. They fail to make distinctions among many different types of products, and contain many errors, contradictions, and unjustified requirements. Requirements concerning the execution (oformlenie) of drawings are constantly increasing."[3]

One of the reasons for the proliferation of standards is

---

[1]E. g., Sadovnichaia and Shevchenko, 1986, p. 12-13.

[2]Katser, 1983, pp. 95-6.

[3]Kulikov and Granovskaia, 1985, p. 108.

that the State committee of standards, its organizations, and sectoral institutes that issue standards are all judged by the number of standards they promulgate. Although some measures for simplifying and improving the system of developing and approving norms and technological documents are now being taken by the GKNT and Gosstandart, they are slow and insufficiently effective.[4]

ESKD (unified system of design documentation) is the system of standards that draws the most criticism. It has been changed 3 times in a period of 5 years in the early 1980s. It regulates minute details and is excessive. Because of ESKD, designers spend 30-50% of their time on paperwork (both making the documents to standard requirements, and obtaining the required approvals and signatures).[5]

ESKD lowers the productivity of design by prescribing the same volume of documentation for products intended for mass production and those that will be produced just once.[6] Before ESKD, design documentation for the latter products was much leaner than for the former. ESKD regulates the form and sequence of producing design documents too tightly for unique machines, leading to a 25-30% increase in expenditures for the preparation

---

[4]Fomin, 1985.

[5]Orlov, 1986, pp. 42-3. The State committee for standards recognizes that the problem with ESKD exists, but points out that collecting signatures in the process of approval is mandated by the ministries (Lyskov, 1982, p. 140).

[6]Orlov, 1986, pp. 42-3.

of technical documentation for unique machines.[7] Another source claims that time spent on producing technical documentation for unique or small-series machines increased several times after the introduction of ESKD.[8] In one case, ESKD lengthened the process from 10 months to 2 years.[9]

In addition to technical design (tekhnicheskii proekt) of unique equipment, new standards require designers to prepare such documents as technical conditions (tekhnicheskie usloviia), patent forms, technical level cards, calculations of economic effect, and certificates from the experts. The cost and time required to prepare and get approvals for these documents in some cases exceed those for design itself.[10]

ESKD was followed by other systems of standards: a unified system of tolerances and fits (ESDP), a new system of measurement units, and ESKD classifier. Introduction of each of these required a revision of design and technical documents. At the institute for the design of electric locomotives, in 1980, 20% of designers were occupied with changing documentation because of new and revised standards.[11]

One result of frequent change in standards is renaming of unchanged parts, substances, and devices. Renaming of unchanged

---

[7] Bykov, 1981, pp. 67-71.

[8] "Tema ...", 1985, p. 129.

[9] Kostin, 1983, p. 32.

[10] Popov, 1986.

[11] Katser, 1983, pp. 95-6.

products also results from simulated innovations which allow producers to raise prices for supposedly higher quality of new product. The epidemic of renaming is said to be a recent phenomenon, and to have spared some sectors (such as instruments industry). It complicates the work of designers who choose parts and devices for their projects harder.[12]

9.1.2 Obtaining approvals.

In addition to the volume and form of documents prepared by the designers themselves, standards and other rules prescribe the list of outside authorities whose approval designers must obtain. The required number of approvals has been increasing, and now consumes a major part of the time of designers. According to one source, the design of a new machine tool requires about 200 signatures of different officials; obtaining these takes 2-3 years.[13] In the experience of one designer, a total of 40 approvals from different organizations has to be obtained.[14] Designers of a packing machine had to obtain 36 approvals on the Union level.[15]

Approvals are required for a variety of purposes and by different authorities. State commissions conducting acceptance tests of new products require 46 documents, and may require even

[12] Pushkarev, 1984, pp. 111-14.

[13] Beshelev and Gurvich, 1986, p. 168.

[14] Fomin, 1986.

[15] Zabulis, 1987.

more certificates and information. The verage volume of obligatory documentation per product is 200-300 pages.[16] The Ministry of the Electrotechnical Industry introduced a new sectoral standard for R&D which requires designers to submit up to 30 acts, certificates, reports, memoranda, etc., in multiple copies. "Head" organizations, which do not develop or produce a product, still have authority in approving the design. For example, one firm that designs equipment has to deal with six such organizations, and they often differ in their opinions and requirements.[17]

Designers have to obtain permission from the supply organs and producers for the use of many parts and materials in the products which they design. This is true for both mass-produced and unique products (i. e., those using both a lot of parts, and a few), and for standard, mass-produced materials and parts (e. g., bearings, anti-friction materials, heat-resistant and special types of steel). To obtain approval for use of ball bearings, designers have to produce seven documents.[18] The number of required approvals has been increasing. "Literally each screw has to be approved, both the standard parts and newly produced ones."[19]

---

[16] Fomin, 1985a.

[17] Fomin, 1985.

[18] Popov, 1986; Pushkarev, 1986, p. 117.

[19] Rassokhin, 1985, p. 29, quoting the chief engineer of "Uralmash".

The organization of design itself has become more cumbersome. Departments of reliability, norm-control, and of chief metrologist have emerged. Designers have become more narrowly specialized. Coordinating these various offices within design organizations is also time-consuming.[20]

Some of the paperwork requiring multiple approval stems from attempts to improve planning and management of R&D. Order for R&D work (zakaz-nariad), introduced first as a part of the new planning scheme in Ministry of Electrotechical Industry (see 9.3.1 below), has to be approved in numerous offices. The burden of obtaining approvals lies with the designers. The same is true for such innovations as the card of technological level of a product that is being developed, and functional-cost analysis.[21]

Bureaucratization of design has been set in motion by attempts to improve its quality. Once set in motion, it has its own momentum, as those charged with controlling design have begun to flex their regulatory power. Other influences are also at work here: machines are becoming more complex, and coordination of designers themeselves is harder; a centrally planned economy has difficulty coordinating the ever-increasing number of producers and users, and designers bear part of this growing burden.

The time needed for completing designs has lengthened. Designers complain of drowning in paper stream, which becomes

[20]Popov, 1986.

[21]Kratov, 1985, pp. 220-1..

stronger every year. No precise data are available on the costs of bureaucratization. According to the most extreme estimate, the share of paperwork in time budgets of designers increased from 20% to 80-90% over 30 years.[22] Other estimates are lower: 30-40% or even 20-25%.[23] Besides consuming time, this process engenders bureaucratic habits of work, and stifles creativity.[24]

9.2 Bureaucratization of inventive activity.

It has been found that independent inventors account for a disproportionate share of major inventions in the West (see Chapter 2). The same has been claimed for the USSR.[25] Changes in the organization of inventive activity in recent decades has worked to stifle individual inventors. Inventions made in the line of duty according to the plan of R&D have become predominant. This should explain the decline in the importance of an average invention, documented in 5.2 above.

9.2.1 The decline of the individual inventor.

In the Soviet patent practice, inventor's certificates are awarded to individual inventors, not organizations. The distinction is made between inventions made by individuals independent-

---

[22]"`Konstruktory' ..., 1986.

[23]Popov, 1986; Pushkarev, 1986, p. 117.

[24]Popov, 1986.

[25]Dudkin and Shimanovich, 1980.

ly, and in the course of a planned R&D project at the inventor's place of work.[26] The share of the latter type of inventions in the total has increased drastically in the USSR in the last 35 years (see Table 9-1).

Table 9-1. Relative decline of independent inventor.

Year	Origin of patent applications, shares, %%.			Share of organizations in all inventions put into State registry, %
	Organizations	Individuals	Foreigners	
1951	20.00			
1965	38.65	60.04	1.32	28.68
1966	48.34	49.16	2.51	52.48
1967	56.08	40.51	3.41	65.58
1968	59.57	36.85	3.58	73.82
1969	64.80	31.38	3.82	78.81
1970	66.19	30.02	3.78	80.41
1971	70.61	25.99	3.40	82.80
1972	73.24	23.47	3.29	83.69
1973	75.58	20.97	3.45	87.35
1974	72.06	23.85	4.08	88.80
1975	71.16	25.48	3.36	87.73
1977	76.65	20.91	2.44	89.84
late 70s-early 80s	80.00			
1985	90.00			

Source: 1965-74 - Table 5-1. 1951 and "late 1970s-early 1980s"- Kosov, 1983, p. 56. The 80% share is frequently mentioned in several sources around 1980, e. g., Artem'ev and Kravchenko, 1977, p. 33; Minin, 1980, p. 76. (Kosov also gives a different share for 1967: 59.4%). 1985 - Naiashkov, 1986, p. 2.

The decline of individual inventor and the rise of organizations in the USSR occurred strikingly quickly. The number of registered planned inventions more than doubled in 1966, almost

[26] In the West, firms receive patents for inventions made on the job.

doubled in 1967, and grew by about 50% in 1968 (Table 9-2). Organizations' share of registered inventions shot up from 29% to 74% in this period (Table 9-1).

Table 9-2. Absolute decline of independent inventor.

Year	Patent applications				Registered inventions		
	Total	Organi-zations	Indivi-duals	Foreign	Total	Organi-zations	Others
1965	95026	36723	57053	1250	10146	2910	7236
1966	98507	47614	48423	2470	13226	6941	6285
1967	100570	56400	40743	3427	20336	13337	6999
1968	110428	65784	40694	3950	25453	18790	6663
1969	118998	77105	37347	4546	26626	20984	5642
1970	132452	87676	39764	5012	32466	26105	6361
1971	153907	108670	40000	5237	35632	29505	6127
1972	155470	113873	36485	5112	41148	34435	6713
1973	163254	123388	34231	5635	50519	44129	6390
1974	143422	103353	34211	5858	43044	38225	4819
1975	152464	108488	38846	5130	44121	38705	5416
1977	165490	126847	34605	4038	48652	43710	4942

Source: Artem'ev and Kravets, 1977, p. 47; 1979, p. 50.

The number of independent applications and inventions declined not only relatively (Table 9-1), but also absolutely (Table 9-2)! The absolute number of patent applications from individuals declined by 40% from 1965-75. The number of inventions registered in the State registry by independent inventors and foreigners ("Others") declined by 33% during the same period (Table 9-2).[27]

The relative decline of independent inventors is a worldwide phenomenon, although its speed and depth in this case is surpris-

[27]There are two types of data for patents granted: "number of inventions registered in the State registry", and "number of recognized inventions". I do not know what the difference is.

ing. But how can one account for the absolute decline? One explanation would be that independent inventors obtained jobs in the organized R&D sector and continue inventing according to the plans. However, this could only occur slowly. The abruptness of the decline of the independent inventor suggests that discrete events (e. g., changes in organization and planning of patenting) discouraged the independents and opened the gates to the flow of planned inventions.

9.2.2 The causes of decline of the independent inventor.

9.2.2.1 General bias of the patent office.

The atmosphere of the relations between the applicant and patent expert is one of hostility, with experts seeing their task as one of not granting a patent.[28] This discourages many inventors.[29] An individual inventor who disagrees with the expert's ruling on his application finds himself fighting a huge organization. He can appeal to three more bodies, each of which is, however, subordinate to the same State committee for inventions as the original expert.[30] Negative responses that later turned out to be wrong constitute 1-4% of positive responses,

---

[28]Glavatskii, 1982, p. 26; Parfionov, 1985; "Vklad novatorov", 1985.

[29]Danilov, 1980, p. 98.

[30]Dudkin and Shimanovich, 1980, pp. 86-9.

according to the chairman of the patent office.[31] But many positive rulings are issued only after a lengthy dispute between the expert and the applicant.

We have no evidence on the change in these attitudes over time, but it is hard to imagine that in the 1950s and early 1960s, when independent inventors supplied the majority of inventions, the attitude was similarly negative. Most likely, it worsened with time, as policies increasingly stressed organized, planned inventive activity.

9.2.2.2 Difficulties in getting royalties.

The individual inventor is entitled to royalties from the use of his invention. The enterprise or ministry that was the first to implement an invention has to pay royalties for itself and all the subsequent users in other ministries. The latter have to reimburse the former for the part of royalties paid on their behalf. But the original users have to pay the full amount of royalties irrespective of reimbursment by other users.[32] Therefore, enterprises fail to notify inventors of the fact of implementation (as they are required to do by law) and intentionally underestimate the economic effect of implementation to make royalties smaller.[33]

Many disputes over royalties of individual inventors end up

[31] L'ianov, 1985.

[32] Sbornik, 1983, p. 319.

[33] Reut, 1985; also Chubarov, 1984 and Obukhov, 1986.

in court. The cases drag on for many years, partly because they require a lot of expert testimony, and experts often procrastinate. The Supreme Court of the USSR instructs lower courts to take the side of inventors. However, according to at least one lawyer, courts usually balk at awarding the large sums of money involved, and experts, who are interested in repeat invitations, often adapt their findings to the courts' known bias against awarding disputed royalties.[34] Apparently, there is no punishment for managers who refuse to pay royalties.[35] Delays in paying inventors' royalties on successfully implemented inventions are quite long, up to 10 years.[36] Since the inventor is paid only upon implementation of his invention, and it is easier to implement small, incremental inventions, this also stimulates a supply of low-caliber patent applications.

We lack evidence that it became increasingly hard over time for the independent inventor to receive royalties.

9.2.2.3 Increasing requirements to patent applications.

The process of applying for a patent has become so bureaucratized and cumbersome that it discourages people from patenting their findings.[37] The requirements for the presentation of

[34] Chertkov, 1985.

[35] Parfionov, 1985.

[36] Orlov, 1986, p. 38.

[37] Popov, 1986; Parfionov, 1985; also Voronov, 1984, pp. 118-9, reviewing letters from inventors.

patent applications were raised in 1973.[38]

Before 1973, the application had to include only description and drawings; now four more documents have to be submitted with the application: a certificate of novelty and usefulness, a certificate of patent search; a certificate of creative participation; and annotation.[39] Some requirements are just impossible to observe: e. g., making a patent search for 7 countries and 30 years would cost 6 thousand rubles if done by the special firm "Patent". It cannot be done even in many large cities, because of a lack of information.[40]

It is only for an individual inventor that the requirements and the policy of the State committee on inventions is onerous. Institutional inventors, working towards plan fulfillment, easily overcome those.[41] Organizations have the resources to make a patent search, conduct experiments, and manufacture a mock-up for their planned inventions.[42]

The individual inventor usually cannot do experimental testing and satisfy other requirements, and is forced to procure help from others by including them among the co-inventors. Multiple authorship of inventions has reached proportions unknown in

---

[38]Kolesnikov and Obruchnikov, 1979, p. 79.

[39]The last item is obligatory for institutional applications only. Dudkin and Shimanovich, 1980, p. 89.

[40]Glavatskii, 1982, p. 24.

[41]"V vikhre ...", 1982, p. 37.

[42]"Vklad novatorov", 1985.

other creative fields.[43] Inventors spend up to 70% of their effort on satisfying the formal requirements, manufacturing, and implementing of their invention, and on getting the royalties paid.[44] More cumbersome requirements in the form of the application make it easier to turn down an application as not conforming, rather than as lacking merit.[45]

9.2.3 The rise of planned invention.

At NII, KB, and R&D units at teaching institutions, there is a strong pressure to patent, expressed in plan targets for patent applications.[46] The plan for inventions is analogous to the plan for the volume of output; it does not take into account the quality of patents. Yet planning establishing invention targets is the thrust of the work of the State Committee for Inventions. One inventor claims that with experience in putting together applications and access to existing patent information, one may reach any patent target with minute, unimportant improvements to existing technology.[47]

Authors of planned inventions are rewarded when they obtain

[43]Minin, 1979, pp. 68-9.

[44]Orlov, 1986, p. 38.

[45]Reut, 1985.

[46]Kolesnikov and Starovit, 1984, p. 127. E. g., a department of Kirov polytechnical institute had a 1985 target of 6 patent applications (Riabov, 1986).

[47]Glavatskii, 1982, p. 25.

their author's certificates. The amount of reward (20 to 200 rubles, up to 50 rubles per individual) is established by the ministry.[48] This is probably a smaller but much more certain reward than the royalties of individual inventors.

9.3 Innovations in planning and organization of sectoral R&D.

We discuss here the consequences of the 1968 reform measures, with one major exception, mergers of sectoral R&D units with production enterprises into associations. These mergers are still a current policy objective, and will be analyzed in Chapter 15 with other policies and reforms. Here, we will just note that mergers put R&D under closer control of the ministries and enterprise managers, with effects similar to those described in 8.4.2.1.

9.3.1 Minelektrotekhprom system.

The 1968 decree ordered an experiment with a new system of R&D management in the Ministry of Electrotechnical industry (Minelektrotekhprom; see 3.6). This system spread to other industrial ministries during the 1970s. A 1983 decree ordered its spread to the construction, transport, communications, geology, agriculture, and supplies sectors.

The spread of the Minelektrotekhprom system throughout the economy is the spread of the structures created for applied

[48] Sbornik, 1983, p. 318.

research to fundamental technical research.[49] It places R&D under tighter control of the ministries by unifying the sources of financing and the planning system; increases the reliance on R&D contracts with enterprises; and ties remuneration of R&D personnel to the economic effect of the implementation of their results.

The predictable result has been a decline in the extent of mission-oriented and fundamental technical research, and an increase in small applied projects, in which ministries and enterprises are interested the most, and which bring fast economic payoff. If in 1969, 20% of science and technology expenditures in the electrotechnical industry went to fundamental research and experimentation, in 1972 only 15% went to these uses, and these funds were restricted to sectoral problems only. In the following years, in many leading institutes of the electrotechhnical industry, the scale of fundamental research was declined. For example, in VNII of electrothermal equipment, the share of fundamental research fell from 8.2% of expenditures in 1973 to 2.7% in 1977.[50] The share of mission-oriented research in machinebuilding R&D also declined in favor of routine applied research, apparently as the result of the spread of the Minelektrotekhprom system.[51] The Ministry of Petroleum Industry required its institutes to increase the number of projects with a

[49] Rassokhin, 1985, pp. 153-4.

[50] Rassokhin, 1980, p. 54.

[51] Rassokhin, 1985, pp. 105-6.

short payoff period after the switch to the new system.[52]

Apparently, the number of small projects greatly increased, as witnessed by the increase in the number of projects in progress. In Minelektrotekhprom, the volume of projects in progress increased 2.6 in 1971-5, and 3.6 times in 1971-78, while the volume of completed projects increased 1.4 times and 1.7 times, respectively.[53]

Ministries and enterprises have always been interested in small R&D projects with a short payoff period and in pushing R&D organizations in this direction.[54] With bonuses to R&D personnel tied to the economic effect of the implementation of their results, researchers aquire a similar interest. Creators of a radically new technology may receive the full bonus for the economic effect of the technology in 9-10 years, when it is fully implemented. Until then, they receive only 30-40% of the future bonus (for projects taking longer than 2 years).[55] If the economic effect of implementation is 50,000 rubles, 4-6% goes into a bonus fund; if 500,000 rubles, this figure is up to 2%. This means that many small innovations bring more into the bonus

---

[52] Khurshudov, 1986.

[53] Interestingly, the share of funds used for R&D expanded at the expense of financing the implementation of new technology. (This is an estimate: ministries do not account or plan for these two uses separately.) Riabushkin, 1985, p. 152.

[54] See 8.4.2.1.

[55] Zavlin and Iudelevich, 1985, p. 93, quoting Pravda, June 23, 1983.

fund than one large innovation.[56]

This makes design and technological organizations interested in creating technology that is not radically different from the existing one, and which can be created fast and easily. Two types of projects are the most advantageous under the new incentive system: short-run projects, in which bonuses can be received within one year; and projects for which the economic effect is not calculated, and the bonus is paid as a percentage of wage fund. With the adoption of the new planning and incentive system, the share of short-run projects and projects for the creation of technologies that have analogues has been increasing. Research projects are becoming smaller and shorter.[57]

Tying bonuses to economic effect leads to further bureaucratization. Economic effect calculations can be easily manipulated to increase bonuses. A large number of regulations to control the quality of R&D work have been introduced, apparently to guard against such abuse. The number of these regulations in the petroleum industry quickly exceeded 1000 (some of them are quite thick). They relate both to large projects and to minor improvements, and are strictly enforced. Violation of a regulation may result in the project not being accepted. It is impossible to follow all the regulations; inferior technical solutions are made

---

[56] Zavlin and Iudelevich, 1985, p. 68.

[57] Orlov, 1986, p. 36. One source refers to strict enforcement of annual economic effect targets causing institutes to abandon all long-run projects (Babanin, 1986). Other information suggests that this is not a high priority target (see 3.5.2).

with the sole purpose of satisfying the regulations. The term of expiration of regulations is being shortened from 5 to 3 years, making the flurry of paperwork even worse.[58] Another byproduct of tying bonuses to economic effect has been the exclusion of consulting-type work that serves to spread others' research results. Bonuses are awarded only for implementation of one's own results, not somebody else's.[59]

9.3.2 Programs.

Programs (similar to PPB) are described in 3.5.1. Their objective is to coordinate research and development across departmental barriers. Under this system, R&D organizations are enlisted into programs without their knowledge and consent, and become overloaded with participation in various programs. "Head" organizations in the program are responsible for the outcome, although they have no way to influence other participants. Head institutes are being reoriented more and more towards coordination and work of other organizations, at the expense of own work. And these are usually academically the strongest institutions.[60]

9.4 Increasing overhead in R&D.

An increasing number of standards, rules and regulations, planning and management procedures, incentive schemes, programs,

---

[58] Khurshudov, 1986.

[59] ibid.

[60] Trapeznikov, 1987.

etc., require time and manpower for their development, enforcement, and updating. Most of this work is being done by the personnel classified as working in R&D.

About 500,000 people out of a total of 4,500,000 employed in R&D are engaged full time in organization, planning, and economic analysis of R&D. This is in addition to the time spent by researchers on these tasks (from one third to one quarter of them spend more than half their time on such tasks).[61] That is, the total time so spent exceeds 25% of all time worked in R&D. We do not have numbers for earlier years, but since the tasks of planning and managing R&D have become so much more varied, numerous, and complex, it is reasonable to assume that this share was lower in the 1950s.

The share of R&D personnel in clerical and administrative positions declined from 9.9% in 1955 to 6.7 in 1960 and to 6.1%-6.2% in 1965-7.[62] The initial decline probably reflects the results of rapid expansion of R&D employment, when administrative positions did not keep pace. Regular campaigns for cutting overhead staff, ordered by the Ministry of Finance, insure that it remains low. But this has nothing to do with the amount of administrative work, which has been expanding, and thrust upon researchers, not administrators.

In 8.4.1.1, we expalained that ministries shift part of the task of administering the sector to R&D institutes. It is only

---

[61]Riabushkin, 1985, p. 120.

[62]TsSU, 1968.

logical to do the same with administering R&D itself. One reflection of the increasing use of R&D personnel in planning and management is the increase in the number of science workers-economists. Their number showed the greatest increase of all categories of science workers by discipline in 1951-74: seven-fold. The share of economists in the total number of science workers increased from 2.8% to 6.9% (see Table 14-1). This is a very imperfect indicator of the process in question, for it counts teachers of economics, and does not count specialists in technical sciences who engage in planning and management.

9.5 "Scientific bias".

9.5.1 Research versus development.

The great explosion of R&D employment in the late 1950s-early 1960s concerned mostly the organizations intended to carry out research (see Table 9-3). Development organizations grew more modestly.

Table 9-3. Employment by type of R&D organization, thousands.

	1960	1965	1968
Science establishments total	866.8	1849.5	2804.0
science workers	354.1	664.6	822.8
Design organizations	120.2	149.5	223.8
Testing and experimental bases	397.4	434.0	573.1

Source: Uvarova, 1973, p. 236, quoting Zaitsev and Lapin, 1970, p. 15. Note: Data do not add up to R&D employment totals; 1960 and 1965 are quite close, but 1968 is far above.

According to TsSU, the number of sectoral NII increased 2.3 times during the period from the mid-1950s to mid-1960s, and the

number of their employees increased five-fold. At the same time, the number of design and technological organizations, which carry out development work, increased 1.3 times, and the number of their employees, 1.6 times.[63] Over the 1960s, the number of researchers increased 2.5 times, employees of design organizations, 1.9 times, and employees of tasting and experimental facilities, 1.5 times.[64]

Employment in experimental-design and experimental-testing organizations also lagged behind that in research. The share of these organizations in total employment fell from 54% in 1960 to 35% in 1968.[65] Growth in the number of design and research units of the enterprises far outpaced growth of employment in such units. The average number of employees declined from 24 in 1955 to 17 in 1966, and of engineers, from 10 to 6.66

On the other hand, the number of employees of specialized design bureaus increased by a factor of 2.5-2.7, and their wage fund, by 3.5 in the 1960s.[67] It is not clear whether these bureaus were singled out of all development organizations for

---

[63]Gliazer, 1971, p. 25.

[64]Golosovskii, 1973, p. 123.

[65]Kosov, Ye. V., "Intensivnyi put' razvitiya i problemy upravleniya", in: <u>2-ya Vsesoyuznaya nauchno-tekhnicheskaya konferentsiya. Problemy nauchnoy organizatsii upravleniya sotsialisticheskoi promyshlennostyu.</u> no. 6, Tezisy dokladov. Sektsiya no. 5. Moscow: 1972, p. 58, as quoted in Yampol'skiy and Galuza, 1976, p. 91.

[66]Gliazer, 1971, p. 25.

[67]Dronov and Shatokhina, 1970, p. 111.

accelerated growth, or whether the authors got their data wrong.

Development is generally more resource intensive than research. The significantly slower growth of development compared to research in the late 1950s-1960s should mean that new research results could not be developed. The problem with these data is that many research institutes in machinebuilding are in fact doing design work, and not research.[68] Still, the discrepancy between the growth rates of the number of researchers and of designers is so large as to suggest a disproportion between research and development.

It can be confidently stated that growth in experimental and testing organizations has been insufficient for the needs of research and development. Witness all the R&D organizations that are unable to conduct testing or pilot production and are reduced to producing paper (see 8.4.1.2).

Even when a research institute in fact engages in development, it has been argued that it does not do it as well as a design bureau would do. "There is a great number of NII which in principle cannot engage in scientific research, because they face a narrow technological problem, and not scientific one. But this scientific mimicry allows them to exist for many years without producing technical solutions. NII of machine tools is not more scientific than the Tupolev airplane design bureau, both should engage in design, but the former manages to escape much of the

[68] Zavlin, et al., 1973, pp. 4-5.

burden by upgrading itself to research status."[69]

It is not clear why the disproportion between research and development arose. My only guess is that research was immensely prestigious at the time, and therefore all authorities scrambled to found research institutes. The same attitude can be seen in the spread of scientific requirements into the design sphere. Dissertations have to be "scientific". (And it is the dissertation that increases salary, and gives one the right to additional residential space and a more desirable status). Though formally inventions and important designs can be presented as dissertations, in fact "scientific contribution" is usually required. So technical achievements are either rejected as dissertations, or authors have to manufacture the scientific part artificially. This takes away their time from what the author does best-design.[70]

9.5.2 Researchers versus support personnel.

Another manifestation of scientific bias has been faster growth in the number of researchers than of support personnel in R&D. One measure of this is provided by the ratio of science workers to support personnel (Table 9-4). This ratio increased somewhat in the 1950s, but then drastically declined in the 1960s. Somewhat different data in Table 9-5 show the decline in the number of technicians per engineer in R&D in the 1960s, after

[69] Mel'nikov, 1985, pp. 50-3.

[70] Bykov, 1981, p. 72; Mel'nikov, 1985, pp. 50-3.

some increase in the 1970s.

Table 9-4. Science workers and research personnel in the USSR.

Year	Science workers, thousand	Support personnel, thousand	Support workers per science worker, ratio
1950	162	552	3.40
1955	224	768	3.42
1960	354	1349	3.98
1965	665	1960	2.96
1970	928	2310	2.49

Source: Iuzufovich, 1980, p. 87, based on Ie. L. Grazhdannikov, Prognosticheskie modeli sotsial'no-demograficheskikh protsessov. Novosibirsk, 1974, pp. 87, 88.

Table 9-5. Engineers and technicians in science and science services.

	1955 July 1	1960 Dec. 1	1965 15 Nov.	1970 16 Nov.
Engineers, thousand	89.4	264.4	419.7	617.8
Technicians, thousand	61.0	193.0	279.1	377.0
Number of technicians per engineer	0.68	0.73	0.67	0.61

Source: Narodnoe obrazovanie, 1971, pp. 238-9.

The generalized picture of changing shares of researchers on one hand and designers and support personnel on the other is given by the ratio fo science workers to R&D employment (Table 9-6).[71] In interpreting this ratio, one should bear in mind that the two statistical concepts are not compatible (see 3.3.1 and Appendix A.2). The ratio of science workers outside industry and teaching institutions to R&D employment in the same Table 9-6 is

[71]Sominskii and Torf, 1972, p. 45.

Table 9-6. Science workers as a share of R&D employment, %%.

Year	Science workers old series	Science workers new series	Science workers outside industry & VUZy old series	Science workers outside industry & VUZy new series
1950	22.76		9.87	
1953	22.31		9.30	
1955	22.57		9.73	
1956	21.93		9.73	
1957	21.66		10.06	
1958	21.23		10.54	
1959	21.21		11.27	
1960	20.09	22.16	11.35	12.52
1961	20.10		11.86	
1962	23.70		13.51	
1963	23.88		13.79	
1964	24.51		14.29	
1965	25.32	27.68	14.87	16.26
1966	25.99			
1967	27.02			
1968	27.52			
1969	28.24			
1970	28.65	30.93		
1971	29.72			
1972	29.80			
1973	29.68			
1974	30.27			
1975	30.24	32.28		
1976		32.47		
1977		32.24		
1978		32.29		
1979		31.44		
1980		31.36		
1981		31.52		
1982		31.99		
1983		32.21		
1984		32.47		
1985		32.74		

Source: NKh.

more meaningful.[72] Data indicate a steady increase in the share of researchers in total employment in the late 1950s and 1960s, and stability in the 1970s and 1980s.[73] This reflects both increasing share of research at the expense of development, and increasing share of researchers at the expense of support personnel.

There are several causes of increasing researcher/support personnel ratio. One in the scientific bias described in the preceding section. Another is low pay in support positions relative to similar positions in industry, which leads employees to leave for jobs outside R&D (see Chapter 11 on that). This leaves scientists and engineers to do the work of technicians and workers. Salaries in R&D are significantly higher for those with scientific degrees. Therefore, all engineers try to defend dissertations as a way of increasing their salaries; this leads them into the ranks of researchers. Yet another cause is the way personnel is managed in R&D organizations. Regular cuts in administrative personnel cause their number to grow slower than that of scientists and engineers. Their positions are the first to be eliminated under any staff reduction in science organiza-

---

[72]Moreover, since the share of science workers in teaching insitutions among all sicence workers has been falling in the late 1950s-early 1960s (see Table 8-1), our ratio underestimates the increase in the share of researchers in all personnel.

[73]This general trend is not visible in the data for Ukrainian and Bielorussian Academies (see Appendix A.9)

tions.[74] Support personnel serves as a buffer, to preserve the cadre of researchers against cuts.[75]

Declining share of support personnel in R&D is also connected with the larger situation on the labor market: unwarranted expansion of higher education, underdevelopment of special secondary education (which produces technicians), and excess demand for blue collar workers.[76] There are few takers for the technician or worker positions in R&D, and an excess supply of people with engineering diplomas. Facing such a labor market, R&D organizations change their organizational charts and job descriptions so as to allow themselves to hire the available labor (engineers) to do the work of those who are not available (technicians, draftspersons).[77]

Increasing researcher/support personnel ratio lowers productivity of R&D. Understaffing of auxiliary units is felt by all research organizations. As a rule, there are two science workers for each technician or laboratory assistant, though it would have been more rational to have the reverse ratio.[78] In the Academy of Sciences, even a senior researcher usually does not have an assistant and a typist/stenographer, and has to be his own re-

---

[74] Efimov, et al., 1985, p. 104.

[75] Nedil'ko, 1985, p. 83.

[76] See "Osnovnye napravleniia perestroiki ...", 1986; Kontorovich, forthcoming.

[77] Kachanov, 1986.

[78] Efimov, et al., 1985, p. 104.

search assistant and secretary.[79] Asked about the greatest problems in their work, researchers in two surveys in the 1970s gave the highest rank to the lack of auxiliary and service personnel (49% and 30% of answers).[80]

As a result of cuts in administrative personnel, department and laboratory chiefs have to carry unnecessary administrative load, such as procurement of supplies.[81] The recommended proportions for NII are 30% of science workers, 7-10% of administrative and clerical personnel. A survey of 120 scientific and technological organizations in Leningrad found that only in 30% of organizations there were less than 120 employees per one administrative worker, in 60%, 10-12, and in some as many as 30.[82]

Lack of support personnel is also felt in design. Detailed drawings require 50% of labor in instruments design. This work is performed by designers of all levels of qualification, because of the deficit of technicians-draftspersons.[83] Lack of technicians and draftspersons in sectoral NII forces designers to perform large volumes of routine work such as copying and reproduction.[84]

---

[79]Sokolov and Reimers, 1983, p. 78.

[80]Sheinin, 1980, p. 93.

[81]Efimov, et al., 1985, p. 104.

[82]Bliakhman, 1979, p. 89.

[83]Ianson, 1985, p. 51.

[84]Chudesova, 1973, p. 104; Kachanov, 1986.

The worsening disproportion between research and development depresses R&D productivity in terms of prototypes created. The effect of the worsening disproportion between researchers and designers and support personnel is the same. This disproportion has been caused by the arbitrary allocation of resources from the center. This is why it is analyzed together with other "bureaucratizing" influences.

Chapter 10. The Academy becomes more applied.

10.1 Why the Academy is stronger than other systems of R&D.

If the results of applied research and development can be competently judged by users, the only check on basic research is the opinion of qualified fellow researchers. And the degree of certainty in any judgement about usefulness of a certain project is lower here than in applied research. Scientists doing fundamental research are on their own; the public that provides the funds cannot directly control them. It is in fundamental research, conducted in the Union Academy, that Soviet science reaches its highest achievements.

Union Academy is an old institution that has long been devoted to scientific pursuits and has formed internal standards of excellence. These standards are perpetuated by recruiting the best and the brightest people for whom research is an important value. Directors of institutes are often themselves great scientists, who value science quite apart from the social recognition it brings them. These people directly participate in the world scientific life; some of them hope to win the Nobel prize. The Academy was one of the few institutions where the Soviet state was slow in destroying old traditions. When organizational controls over an activity fail, professional ethics fill the void.[1] In this case, ethics are transmitted through tradition and maintained by selectivity and elitism.

---

[1]Arrow, 1969, p. 62.

The problem with ethics is that it does not travel well. When rapid expansion occurs, large numbers of people are admitted who are not inculcated with ethics. This is especially true when R&D expands in the areas where there is no tradition of this sort of ethics, such as industry or Academies in the peripheral republics. Creation of affiliates and centers of the Union Academy in the peripheral areas of the Russian republic may also have had similar effects.[2]

10.2 Difficulties in cooperation between the Academy and sectoral R&D.

Fundamental research is the statutory mission of the Union Academy. The architects of Soviet R&D intended it to develop new ideas, that would then be transferred to sectoral institutes for elaboration and development. However, this scheme does not work. Academic science offers its ideas directly to the national administrative organs, not to applied R&D institutions. The latter often are not directly connected to basic science and sometimes even ignore it.[3] The recommendations of academic institutes for further development of their results are, as a rule, ignored by sectoral NII.[4] Only 30% of these recommendations are accepted

---

[2]Prokhorov, 1986, complaints of management difficulties for the division of physics now that institutes are so widely dispersed.

[3]Sokolov and Reimers, 1983, p. 73; "Tekhnologicheskii ...", 1986, pp. 55-6.

[4]E. g., Shemiakin, 1986.

for further development.[5]

The explanation for the difficulties in transfer of R&D results from the Academy to sectoral R&D lies in the characteristics of the latter that were analyzed in Chapter 8. Sectoral institutes are not willing to develop the results of fundamental research because of the tendency to produce incremental improvements, which allows them to increase output volume, and because of the general lack of interest in innovations, especially radical ones. Utilization of new results of fundamental research often requires redeployment of resources among topics and organizations, which is hard to manage under current arrangement (see 3.4.2 and 3.5.3 above). Preoccupation with small improvements leaves few resources for development of the results of the Academy. According to one estimate, 10% of resources of branch institutes currently go towards research, and the rest, to design, testing, etc.[6] Academic institutes are considered to be competitors for funds by the sectoral institutes, jealous of outsiders' results and imbued with narrow departmental ambitions. Plagiarism, in which the rejected result of an academic institute is later represented as one's own, is not infrequent, and poisons the atmosphere.[7]

---

[5]Derevianko et al., 1985, p. 186.

[6]Bliokov, 1984.

[7]Bliokov, 1984. See also Gliazer, 1979, p. 32.

10.3 Getting the Academy to do the work of sectoral R&D.

The weakness of sectoral R&D leads economic officials to demand the Academy's participation in sectoral applied research (see 8.5). Involvement of the Academy in all stages of the innovation process became the official policy in the 1970s.[8] The work of the Academy has become more applied, deviating from its traditional and statutory mission of basic research.[9] Academic institutes are ordered to participate in the goal-oriented programs of GKNT and programes for solving the most important science and technology problems (see 3.5.1). It is estimated that work on the programs is 50% applied.

The Union Academy again "widens the network of institutions in technical sciences." The division of data processing, computers and automation has been created, and a number of institutes and their affiliates was founded. A division is also being formed to work on the theoretical foundations of machinebuilding, based on existing and newly formed institutes.[10] This represents the reversal of the transfer of technical sciences institutes from the Academy to sectoral R&D in 1961 and 1963 (see 3.2.1).

Research on contract with enterprises is another factor leading the academic institutes to abandon their traditional fundamental specialization, and carry out internally all stages

---

[8]Gustafson, 1981, section 6; Kassel and Campbell, 1980.

[9]The rest of this Chapter draws heavily on Bliokov, 1984.

[10]"Kliuchevaia ..", 1986.

of R&D. While encouraged by the government, contract research is also in the interest of academic institutes. The benefits of contracts for institutes include:

- practical testing of results;
- access to the customer's testing and experimental facilities;
- obtaining financial resources for procurement of supplied and paying for business trips;
- increase in wage fund, number of employees, bonus fund.

These benefits are especially important in view of scarce budget funds and restrictions on their disbursement.[11] Apparently, they outweigh such drawbacks of contracts as uncertainty and instability compared to budget financing, and payment by stage which makes it hard to buy capital items.[12]

To attract customers, institutes have to offer usable product, not just ideas. Fundamental science has to create its own applied science and production facilities, in order to develop its results.[13] Models of technical devices, substances, and technological processes increasingly represent the output of academic institutes. Their laboratories, design and experimental production units, which previously exclusively served the needs of their own fundamental research, increasingly serve outside customers. It is estimated that 10% of the total capacity of

---

[11]Bliokov, 1984, p. 37-8. This source claims that the benefits are ranked in the order of importance.

[12]Nedil'ko, 1985, p. 76.

[13]Sokolov and Reimers, 1983, p. 73; "Tekhnologicheskii ...", 1986, pp. 55-6.

such services is used in this manner, and in some institutes, up to 50%. Academic institutes have managed to divert the funds of ministries and enterprises from sectoral institutes in this manner. Now, more than 25% of all contracts are performed directly between enterprises and academic institutes. (Though some institutes still totally abstain from contract work.)

10.4 Increasing share of applied research and development in the Academy's work.

Academies are observed to spend a larger share of their resources on applied research and development.

In the Ukrainian Academy, which is noted for its applied/implementation slant, experimental, design, and testing facilities (apparently, utilized for the needs of implementation, not for the internal needs of the Academy) now include 10 experimental plants, 27 experimental production units (*proizvodstv*), 32 design bureaus, and 5 computer centers. Their annual work volume is almost 250 million rubles.[14] With the expansion of contract work in the 1970s, the Bielorussian academy founded a central design bureau with an experimental production plant, and special design-technological bureaus with experimental production facilities at the institutes of the physical-mathematical and physical-technical divisions.[15]

The increasing share of applied research and development can

---

[14] Pokhodnia, 1986.

[15] Nedil'ko, 1985, p. 74.

also be deduced from the increased portion of financing coming from goal oriented programs and contracts. In 1982, in the Union Academy, half of budget financing (ranging from 25% to 75% for individual establishments) was for research under programs, estimated to be 50% applied. The increase in the share of contract financing can be seen in Table 10-1.

Table 10-1. Share of contract work in total expenditures of Academies, %.

	1965	1970	1971	1975	1978	1980	1982	1983
Union	5	10		14		17		
Siberian division	6	15	16	20-22				
Ukrainian			30		50		over 50	
Bielorussian								53
Kazakh							below 20	

Source: Bliokov, 1984, p. 37; Kanygin, 1974, p. 174; Kanygin and Danilovtsev, 1976, p. 35; Chemodanov, 1978, p. 51; Nedil'ko, 1985, p. 74; Iampol'skii, 1984, p. 205.
Alternative data: Union Academy: 9.5% in 1975, 14% in 1980; all republican: 26 and 37% (this and Kazakh share for 1982 from Riabushkin, 1985, pp. 140-1).

For some divisions of the Ukrainian Academy, the share of contracts reaches 70%.[16]

These data unambiguously indicate the rapid increase in the share of applied research and development in the work of the academies. However, the exact share is hard to establish, because of the difficulties involved in classifying personnel and expenditures by types of work (see Appendix A.6). According to one estimate, the Union Academy's work in the early 1980s was

[16] Iampol'skii, 1984, p. 205.

only 50-60% fundamental, with the rest (in money terms) being applied research, development, and implementation.[17] A sociological survey of researchers in the Union and republican academies in 1969-73 found that 43.5% of them are engaged in fundamental research, 43.4% in applied, and 10.5% in both. The share of fundamental research is higher in the institutions of the Union Academy in Moscow and Leningrad (50.7%), and lower in peripheral institutions and in republican academies.[18] In 1971-5, about 40-50% of work of the Siberian division was considered applied research.[19]

10.5 Subverting the excellence of the Academy.

The process described in this chapter is likely to boost measured R&D productivity, as resources are diverted from the generation of ideas, which is unobservable, to creation of prototypes of machines and inventing. However, it is bound to be detrimental for R&D productivity broadly understood.

Union Academy is getting only 4% of the total R&D funds. The increasing demands on the Academy to lead in development and implementation of technology will take resources away from its main task, fundamental research.[20] This will cripple fundamental

---

[17] Bliokov, 1984.

[18] Kelle, et. al., 1978, p. 121.

[19] Chemodanov, 1978, p. 51.

[20] Members of the Academy are worried by that. See Ginzburg, 1986, pp. 39-40.

research, the only area where Soviet science has world standing.

Involvement in applied work and development gives ministries and enterprises a say in what the Academies are doing. The influence of ministries and enterprises on the academies is likely to be the same as on sectoral R&D. Industry is interested in very mundane, low level applied research, far below the capacity or the intended level of the academy's work. It is not just a switch from fundamental to applied research: it is a switch to incremental improvement of existing technologies, away from creating new technologies.[21] It is bound to be demoralizing for the academic researchers, lower their qualification, and damage the only island of excellence in Soviet R&D.

[21]Rassokhin 1985, p. 106.

PART IV. OTHER CAUSES OF PRODUCTIVITY DECLINE AND COUNTERVAILING FACTORS.

This part investigates groups of factors influencing R&D productivity: expenditures per employee (salaries and equipment); factors stemming from the slowdown in the growth of the sector in the 1970s; and countervailing factors, which have been pushing R&D productivity higher during the period we consider.

Chapter 11. Expanding R&D on the cheap: labor.

So far we have analyzed only the quantitative growth of R&D employment. Did the *average quality of employees also change* in the past thirty five years? To answer this question, we consider changes in R&D salaries relative to wages in other sectors, and the consequences of these changes.

11.1. Salary in R&D declines relative to the other sectors.

11.1.1 The data.

In 1950, the average wage in R&D was higher than that in industry, construction, or transport, by one third to one half (see Table 11-1). This differential rapidly eroded, to 15-20% in 1960. By mid-1960s, construction caught up with R&D, and in 1968 overtook it. Transport overtook R&D in 1971, and industry, in 1974. The R&D wage now lags by 5-15% behind that of industry, construction, and transport. The lag behind the wage of engineers and technicians (ITR) in industry is even larger. In

fact, the average worker in industry in the 1970s and 1980s earned more than an average employee of R&D (average industry wage was very close to average wage of workers).

Table 11-1. Average money monthly wage in science and science services compared to other sectors, %.

Year	Industry Average	Industry Engineers & Technicians	Construction	Transport
1950	132.29		153.72	131.91
1955	131.29			133.51
1960	114.13	81.58	112.04	120.18
1961	111.32			113.00
1962	111.90			110.87
1963	111.48			110.47
1964	111.44			109.59
1965	111.91	81.27	103.31	109.57
1966	111.05			108.21
1967	109.22			105.63
1968	106.07		98.55	102.46
1969	103.84		94.78	100.99
1970	102.63	78.37	91.26	100.07
1971	102.18	77.59	91.26	97.85
1972	101.06	78.68	90.20	95.23
1973	100.07	79.66	90.04	94.00
1974	98.39	79.11	90.00	91.62
1975	97.10	79.07	89.08	90.78
1976	95.34	78.52	89.28	88.89
1977	95.08	79.31	88.67	88.29
1978	96.04	81.48	88.85	89.37
1979	96.23	83.10	88.30	90.04
1980	96.82	84.47	88.73	89.79
1981	96.62	85.45	87.49	89.67
1982	97.35	86.69	87.89	90.86
1983	97.34	87.91	87.28	91.26
1984	96.92	86.94	86.52	92.10
1985	96.11	86.79	85.55	91.87

Sources: 1950-1967 - TsSU, Trud v SSSR, 1968; 1968-85 - NKh.

The lag of R&D wages can be fully appreciated only if we look at average educational level across sectors (Tables 11-2 and 11-3). R&D personnel is much more educated than that of all the other sectors; return on human capital is lower there. Even back in 1960, more than a third of R&D employees had special education, compared to only 7.5% of industrial and 4.3% of construction employees.

Table 11-2. Shares of employees with higher and special secondary education in sectoral labor, %.

Year	Industry	Transport	Construction	R&D
1960	7.48	4.33		36.06
1965	9.20	5.57	6.73	37.33
1970	12.17	7.63	9.77	42.52
1975	16.03	9.85	13.52	48.38
1977	17.76	10.65	15.56	52.81
1980	19.62	11.73	17.22	54.50
1983	21.64	12.64	19.29	55.67

Source: NKh.

Table 11-3. Shares of employees with higher (H) and special secondary (Ss) education in sectoral labor force, %.

Year	Industry		Transport		Construction		Science	
	H	Ss	H	Ss	H	Ss	H	Ss
1966	2.79	6.98					25.65	13.35
1977	5.60	12.16	2.67	7.97	5.10	9.96	37.26	15.55
1980	6.36	13.26	3.09	8.64	5.99	11.24	38.27	16.17
1983	7.30	14.35	3.47	9.17	6.97	12.32	40.22	15.45

Source: NKh.

It may even be the case that the wage differential in favor of R&D was insuffiently high even then, given the investment in education, including graduate and postgraduate education, practically absent outside of the R&D sector. Table 11-3 shows that the R&D sector has an unusually high share of people with higher education, 25% in 1966 and 40% in 1983. Comparable shares in industry (2.8% and 7.3%) are lower by an order of magnitude; and in transport and construction, they are still lower than in industry.

Table 11-4. Average monthly wages, rubles.

Year	Science worker, SO AN SSSR	Industry		Construction	Transport
		Engineers & technicians	All employees		
1972	166	182.5	137.9	154.4	144.0
1973	169	184.9	147.2	163.6	156.7
1974	172	193.4	155.5	170.0	167.0
1975	174	199.2	162.2	176.8	173.5

Source: Shcherbakov, 1982, p. 82.

We supplement highly aggregate data on wage differentials by sectors of the economy by micro-observations showing that researchers and designers earn substantially less than workers. In the early 1970s, the salary of science workers in the Siberian Division of Union Academy was already below the average salary of engineers and technicians in industry (see Table 11-4). This is despite the fact that science workers all have higher education, while technicians, part of the latter group, have only special secondary education. By the mid-1970s, average wages in construction and transportation, where the share of employees with

higher education is low, caught up with the salary of science workers.

In the early 1980s, the candidate of science in a position of junior science worker earned 20-30 rubles less than the average worker.[1] The salary of a first category engineer-designer is only 15 rubles higher than that of an engineer-designer of the third category. It is often 2-2.5 times lower than that of a worker.[2] A technician-designer is paid 90-120 rubles, and an engineer-designer, 120-180 rubles, with the upper end of the range applying to leading engineers with 15-30 years of experience. By contrast, machine tool operators earn as much as 250-300 rubles.[3] To supplement their salary, designers moonlight as janitors, letter carriers, nightwatchmen, and construction workers.[4] In an example taken from a machinebuilding plant, blue-collar workers' wages range from 520 rubles for a very skilled manual work to 360 rubles for good workers to 180 rubles at the entry level. The best designers at the same plant earn 175 rubles plus occasional 25-30% bonuses. The chief of the design bureau earns 180-220 rubles.[5]

---

[1]Gukasov, 1984.

[2]Orlov, 1986, p. 36.

[3]Kostin, 1983, p. 28.

[4]"Tema ...", 1985, p. 128.

[5]Shimanovich, 1986, p. 128.

11.1.2 Causes of the decline.

Salaries of people with a scientific degree and/or rank in research and teaching institutions were set high in the late 1940s. They were revised in 1957, and have remained unchanged since then.[6] These high salaries accounted for the higher pay in R&D compared to other sectors. Other personnel (researchers without degrees, engineers, technicians, workers) were apparently paid less than in the other sectors.

The main process that led to the erosion of the pay differential has been the shortage of manual workers that appeared in the early 1960s.[7] This shortage led to the escalation of wages of blue collar workers. Since there were enough bodies to fill vacancies in R&D, pay there did not grow as fast as in the other sectors. This is part of a broader trend, which also caused narrowing of pay differential between workers and technicians and engineers in industry.

In 1969, there was a restructuring of wages in science and science services. The unified system of salaries was introduced, eliminating differences between people doing the same job in different sectors. But no changes were made for those holding scientific degrees.[8] Also, the earnings of blue collar workers and engineers in R&D still appear to be below those of their counterparts in other sectors.

---

[6]Gliazer, 1975, pp. 145-6.

[7]Kontorovich, 1986.

[8]Gliazer, 1975, pp. 145-6.

As the R&D sector expanded in the late 1950s and early 1960s, the share of those in entry level positions, and therefore without degrees, increased. This structural shift depressed salary growth. But then the reverse movement started. The share of candidates of science now has almost reached its 1950 (though not 1955) level; the share of doctors has also has been inching up.[9] This may well be the cause of the stabilization of the relative salary gap in the late 1970s.

11.2 Declining prestige of R&D jobs.

The prestige of scientific and engineering occupations among high school graduates declined in the 1960s and 1970s. Surveys of graduates of Novosibirsk city schools in 1963 and 1973 showed the following declines in the ranks given to occupations: physicist, from 1 to 7, engineer in machinebuilding (presumably, including designers), from 8 to 14 (males); medical scientist, from 1 to 3 (females). Male graduates of Novosibirsk rural schools in the same period downgraded the occupation of mathematician from 9 to 23. Only female graduates of rural schools increased their ranking of scientific occupations: mathematicians from 14 to 10 and geologists from 17 to 4.[10]

A longer-run trend in changes of prestige of R&D occupations is presented in Table 11-5. It indicates a decline in attrac-

---

[9]See Appendix A.5.

[10]Cherednichenko and Shubkin, 1985, pp. 58, 60-61.

tiveness of R&D occupations.[11] The decline in the prestige of occupations of scientists and designers is perceived by many observers.[12]

Table 11-5. Changes in evaluation of prestige of R&D occupations over 20 years in Novosibirsk, 1983 as a % of 1963.

Occupation	Urban		Rural	
	male	female	male	female
Biologist	90.31	104.38	89.38	110.41
Engineer-machinebuilder	77.16	71.75	82.48	75.09
Physicist	74.17	79.04	71.33	91.80

Source: Cherednichenko and Shubkin, 1985, p. 62.

The relative prestige of R&D jobs could not help but suffer from the decline in the relative salary, described in the preceding section. A related cause of decline is the change in orientation of Soviet people towards more materialistic values. Indeed, the occupations which saw the highest increase in prestige are the low-glamour ones that promise high earnings (often illegal, as with sales clerks and waiters).[13] Still another cause of the decline of the prestige of science as an occupation is the decline in the prestige of science itself as a key to the solution of all problems.[14]

---

[11] In 1963-83, the share of students who leave before completing high school declined. To the degree that their attitudes are less favorable to R&D occupations than those of the rest of the students, this may have influenced the results of the surveys. See Cherednichenko and Shubkin, 1985, p. 62.

[12] Sokolov, 1985; Orlov, 1986, p. 37.

[13] Cherednichenko and Shubkin, 1985, pp. 62-3; Shlapentokh, 1985.

[14] This is not a specific Soviet phenomenon.

11.3 Consequences of decline in relative salary and prestige.

11.3.1 Decline in ability of entrants.

The immediate result of the decline in relative pay and prestige of R&D jobs has been a decline in the average quality of entrants into the field. This proposition is impossible to demonstrate empirically, for there are no measures of how able, hard-working, etc. employees in particular fields are. Rather, the decline in the relative pay and prestige of a sector must, under fairly general conditions, lead the best entrants to the job market to prefer other sectors.

It may be argued that science as an occupation requires specific abilities that cannot be realized in other sectors. Someone with abilities for theoretical physics will do best to go into theoretical physics, even if prestige and pay there are relatively low: he or she will be even worse off in any other occupation. This, of course, presupposes that young people know the nature of their abilities. This may be true for some scientific pursuits, and some types of abilities. But it can hardly hold for the mass of rank-and file researchers and designers.

Abilities are distributed very unevenly across human populations. Most people have abilities (as measured, e. g., by IQ) around the mode. As the level of ability grows, the frequency with which it is observed in the population declines rapidly. IQ does not measure scientific creativity. But if the latter is distributed similarly to other abilities, as seems plausible, and

if the R&D sector attracts the most able people, then expansion of R&D employment as a share of the total employment would result in the declining average ability of R&D employees. Soviet R&D employment in fact has been growing as a share of national employment (see Table 1-2). The assumption about R&D as the first choice of the ablest was much truer for the 1950s and early 1960s than for the later years. This means that the quality of R&D personnel was diluted in two ways: first, in order to recruit a larger share of the total population, the R&D sector had to turn to the groups with lower ability (go farther left on the distribution chart); second, the R&D sector lost some of the best and the brightest, who previously would have chosen it, to other sectors, and had to hire more mediocre people instead.

It is in the occupation of designer where the lack of able entrants is felt most directly.[15] There has been a massive out flow of all kinds of engineers, including designers, into blue-collar jobs.[16] The situation of designers at the enterprises is particularly bad, since it is harder for them to prepare dissertations than for those working in specialised R&D or teaching institutions. This forecloses an important way of getting higher pay for them.[17]

The decreasing number of support personnel per researcher and designer, described in 9.5.2, is also partly due to the

---

[15]"Vzyskatel'nost' ...", 1986.

[16]ibid.; Parfionov, 1985a.

[17]Kostin, 1983, p. 27-8.

growing pay differential between R&D and other sectors. This leaves researchers and designers without necessary support, and forces them to do work below their qualification.

11.3.2 Feminization of R&D personnel.

There have been allegations that the declining productivity of science is due to its progressive feminization. We examine here evidence on differential productivity in R&D by sex, and trends in sexual composition of R&D employment.

11.3.2.1 Productivity of women in R&D.

The lower average productivity of women than of men in research and design is a widely accepted notion in the writings of Soviet scientists. "... the drive to seek non-traditional ways of deve-lopment is more frequently exhibited by men than by women, as has been established by psychologists and students of science. Hence, wide feminization of science leads to increase of more detailed projects, and deceleration in development of new fields."[18] Sociologists find that women-researchers are significantly less oriented towards creativity as a motive.[19]

One study found that women have on average 6.2 individually written articles and 7.9 co-authored ones, compared to 8.2 and

---

[18]Sokolov and Reimers, 1983, p 77. Sokolov is academician-secretary of a Division of the Academy of Sciences.

[19]Subbotina et al., pp. 118-119, 1976.

11.8 for men.[20] (It is not clear whether these results are adjusted for the differences in age, degree, rank, position, field, place of work, all of which probably differ for men and women.)

A study of 1000 design engineers in Leningrad found that the average rank of value orientation towards work was higher for men than for women (5.7 and 6.9, with 4.4 being the highest rank on the scale). The study also classified engineers into six groups by professional qualities. The groups with the worst characteristics ("engineers against their will" and "doers, not thinkers") were found to be dominated by women.[21] Designers are particularly concerned with the feminization of this formerly male occupation.[22]

For the purposes of the present study, it does not matter what accounts for differential R&D productivity by sex, as long as the fact itself is established. One reason may be that women spend significantly less of their spare time on professional activities, and more on their families.[23] Poorly paid but clean and quiet jobs in R&D offer working conditions that appeal the second wage-earner in the family.[24] Sociologists find that women evaluate most jobs higher than men do; they are readier to take jobs where a "vacuum of prestige" occurs. The resulting

---

[20] Kugel', 1974, p. 291.

[21] Iadov, 1977, pp. 106, 121, 123.

[22] Kostin, 1983, p. 29; "Tema...", 1985, p. 129.

[23] Blaikhman, 1979, p. 84.

[24] Shimanovich, 1986, p. 128.

feminization of whole occupations is a sign of troubled public perception of this occupation.25

11.3.2.2 The share of women in R&D.

Aggregate data show only modest increases in the share of women among science workers and R&D personnel over the last 35 years, compared to the magnitude of other structural shifts in this period. Yet the increases in certain subsectors of R&D have been more pronounced.

The share of women among all science workers increased very little, from 36.3% in 1950 to 40.1% in 1983 (see Table 11-6). Changes in the share of women in the higher tiers of scientific hierarchy are of particular importance for judging the impact of feminization. These changes can be gleaned from their share in the total number of science workers with ranks and degrees. The shares of women among doctors of science, and among academy members and professors almost doubled (from 7.2% and 5.6% to 13.7% and 10.9%, respectively) from 1951-83, and the share of docents increased substantially (from 14.6% to 24.6%). On the other hand, women's share of candidates of science increased little (25.1% to 28.3%), and their shares of SNS's and of MNS's and assistants actually declined (from 30.7% to 22.4%, and from 52-53%% in the mid-1950s to 45%), as shown in Table 11-6.

Apparently, the increase in the share of women among doctors of science occurred due to the increase in the share of women-

---

[25]Cherednichenko and Shubkin, 1985, p. 49.

doctors in higher education.

Table 11-6. Sex Structure of Science Workers, and of their groups by rank and degree, shares, %.

Year	Total	Doctors	Candidates	Academy members, professors	Docents	SNS	MNS, assistants
1950	36.31	7.23	25.05	5.62	14.68	30.70	47.96
1955	36.44			6.67	16.78	30.14	52.05
1956	36.27			6.59	16.78	30.13	52.25
1957	35.82			6.38	17.09	29.94	53.05
1958	35.70			7.29	16.82	29.07	52.97
1959	35.84			7.22	16.91	29.35	51.33
1960	36.34	10.09	29.30	7.07	9.39	28.57	50.94
1961	37.12			7.77	17.54	28.57	50.52
1962	33.88			8.18	17.98	29.83	50.44
1963	36.19			8.77	20.51	30.62	52.61
1964	37.62			9.17	20.65	30.51	51.87
1965	38.34	9.46	25.89	8.80	19.55	28.92	51.12
1966	38.39	12.05	26.90	8.82	20.08	28.48	48.11
1967	38.30	12.02	26.82	8.84	20.39	27.78	49.46
1968	38.73	12.50	27.20	9.43	20.69	27.35	50.00
1969	38.85	13.30	26.97	9.47	21.57	27.35	50.00
1970	38.79	13.14	27.04	9.94	20.99	25.13	49.80
1971	38.74	13.41	27.29	10.26	21.31	24.53	50.20
1972	39.20	13.17	27.35	10.19	21.95	23.79	49.26
1973	39.65	13.42	27.61	10.19	22.11	24.06	49.47
1974	39.72	13.88	27.04	10.22	22.27	23.87	49.35
1975	39.91	13.93	28.76	10.48	22.30	23.45	49.56
1976	39.72	13.87	28.20	10.42	22.92	23.27	48.76
1977	39.98	14.17	28.18	10.67	23.19	22.93	49.07
1978	39.76	14.21	28.07	10.73	23.57	23.13	47.88
1979	39.62	14.02	28.02	10.78	23.82	22.57	47.75
1980	39.91	13.79	28.04	10.95	23.76	22.58	46.47
1981	39.86	13.95	28.09	11.03	23.85	22.30	44.53
1982	40.11	13.85	27.94	10.80	24.15	22.43	45.07
1983	40.09	13.66	28.30	10.88	24.64	22.45	45.00
1984	39.98	13.58	28.06	11.22	24.57	22.02	44.36
1985	39.95	13.54	28.09	10.97	24.51	21.94	43.58

Source: Table C-1.

This is reflected in the increase of their share among profes-

sors and docents.[26] The decline of the share of women among SNS shows that their presence did not increase in the middle tiers of research institutes. Feminization must have occurred primarily in higher education, the least important sector of R&D.

The share of women among all R&D employees increased by more than their share among science workers (6 percentage points over 24 years against 3.7 points over 35 years: see Table 11-7). This share was stable or slightly declining over the 1950s. Since the late 1950s, it has been rising, and reached 50% in the mid-1970s. The faster rise of women's share in R&D employment than among science workers suggests that their presence was increasing mostly in support positions in science (technicians, laboratory assistants) and in design.

Table 11-7. Share of women in science and science services, %.

Year		Year		Year	
1950	43	1961	43	1969	47
		1962	44	1970	47
1955	41	1963	44	1971	
1956	40	1964		1972	48
1957	40	1965	44	1973	
1958	42	1966	45	1974	49
1959		1967	45	1975	
1960	42	1968		1976	

Source: NKh.

Data on education can serve to approximate data on positions held by men and women in R&D. In 1959, women in R&D were better

[26]The number of professors and academy members is dominated by the former; in 1984, academy members made up only 9% of the group. NKh-84, p. 103.

educated than men, but mostly in the group with special secondary education (i. e., technicians) - see Table 11-8. In science, larger proportions of men had higher education and a less than 7-year education. This means that men were overrepresented both in the higher ranking and manual jobs, and women were overrepresented in the middle-ranking support positions. Yet women had higher educational attainment than men in design, and probably were overrepresented there in all occupations (except for managerial ones). It appears that in the 1960s and 1970s women were increasing their share in those R&D occupations in which they were already well established (overrepresented?) in 1959. Occupations that were already feminized became feminized even more.

Table 11-8. Education of R&D employees by sex, shares, %%, 1959.

	Higher	Higher unfinished & special secondary	Secondary & unfinished secondary	Elementary & unfinished 7-years
Males	20.9	14.3	33.3	25.4
Science	29.3	13.5	30.6	20.4
Design	13.9	15.0	35.5	29.0
Females	21.9	19.4	36.6	12.6
Science	25.5	17.1	33.6	12.9
Design	16.2	23.1	41.3	12.2

Source: TsSU, 1962, pp. 118, 120, 122, 144. Note: "Science" includes auxiliary organizations rendering services to scientific organizations. "Design" includes design and project-design organizations outside of construction, geological survey, hydrometeorological service.

It appears that the share of women increased in teaching institutions, design, and support positions in research.

The share of women is not uniform across scientific disciplines. In institutes of light industry, the share of women among science workers reaches 80%. The share of women in medical and biological institutions is higher than in physics and mathematics.[27] It is not clear whether these differences have increased in the last 35 years.

[27] Kugel', 1974, p. 291.

Chapter 12. Expanding R&D on the Cheap: Equipment.

Theoretical scientists can work at home with pen and paper, but even they would be more productive if they could use good libraries and telephone networks. Most R&D personnel need materials, equipment, and premises to be able to do their work. If these are absent or inadequate, additional personnel will be less productive, or unable to do any work at all. There are loud and convincing complaints about the inadequate "material base" of R&D. We have already dealt with the issue of experimental and testing facilities for sectoral institutes in 8.4.1.2. Academy and teaching insitutions also suffer from poor equipment and inadequate buildings. To lower R&D productivity, the volume of services of equipment and buildings per researcher should decline over time. In the remainder of this chapter, we will try to determine whether this happened.

12.1 Qualitative evidence on lack of equipment and buildings.

In a sociological study of academy researchers in 1969-73, the suppply of materials and equipment received the second highest negative ranking among the conditions of work (less than the organization of auxiliary work, and more than pecuniary incentives).[1] When asked about office equipment they need the most (and apparently lack), researchers in two surveys in the mid- or late 1970s named typewriters (57% and 33% of answers),

---

[1] Kelle, et al., 1987, pp. 129-130.

desk calculators (36% and 47%), xerox (31% and 17%), telephones (27% and 25%), computers (22% and 24%), and dictaphones (15% and 5%).[2] The highest need is for conventional equipment that has been around for a century (telephone, typewriter) or for decades (xerox, dictaphone). It is understandable that the most modern equipment, such as word processors, is not even mentioned. But the computer also ranks fairly low. This reflects several perennial conditions of the Soviet economy: a weak telephone network; a weak office-equipment producing sector; and official fear of proliferation of the means for dissemination of information. These longstanding features of the Soviet economy and society may be increasingly detrimental to the growing R&D sector.

Stringent controls over foreign currency allocation is another such feature. A leading Soviet physicist complains that physics institutes of the Academy have less funds for foreign journals than comparable institutes in India.[3]

Institutes which do not even have an appropriate building and tables and chairs for all employees exist in all regions and branches of R&D.[4] Such institutes occupy makeshift quarters in buildings originally constructed for other purposes (e. g., retail, residential), or in the basements. One organization may be split among a number of locations. Conditions are so crowded

---

[2]Sheinin, 1980, p. 95.

[3]Ginzburg, 1986, p. 42.

[4]This and four subsequent paragraphs are based on Korolev, 1984.

that many employees have to take turns at the workplaces, or to work at home.

The most glaring examples include the Institute of geography of the Union Academy, occupying 24 basements all over Moscow, and having desks for only one third of its employees; some humanities institutes of Moldavian Academy, where up to 70% of researchers do not have desks; a laboratory with 110 rubles of fixed capital per employee; and the Geophysical institute of Union Academy, split among 16 locations, with 2.7 square meters of space per employee. Other organizqations split among a large number of locations, or housed in inappropriate buildings, are the institutes of Gosstandart, Ministry of petroleum, Ministry of coal, Institute of water problems of Union Academy (all in Moscow); institute of physics of Dagestan division of Union Academy; some institutes of Turkmenian Academy; research and project making institute of petroleum industry in Ufa.

There are several reasons for this. Institutes are hastily founded, without regard for supplies and material base (see 7.1 above). The construction of R&D projects faces delays, because it receives low priority relative to other sectors. Plans for commissioning testing and experimental facilities, plants, shops and installations at R&D organizations and enterprises (projects estimated to cost over 3 million rubles) have been fulfilled by an increasingly small margin since 1975, sometimes as low as 44% (see 8.4.1.2).

Part of the problem is regional: the great concentration of

R&D institutions in Moscow, where space is scarce. There have been plans to move 342 organizations with 135,000 employees out of Moscow; just over 40 organizations were moved since 1970. Since Moscow is such a desirable place to live, ministries are still trying to open new organizations there and expand the existing ones. Organizations created in remote areas face the problem of attracting the employees; as a rule, housing has to be constructed, but this has low priority with construction organizations. This applies to Khabarovsk institutes of Far Eastern center of the Union Academy and telescopes in the North Caucasus.[5] Another reason is increase in the number of completed buildings which cannot be used because equipment is lacking (especially in the Academy of Sciences).[6] Most of the biological institutes in Moscow occupy crowded quarters which are not intended for R&D use and lack equipment and supplies.[7]

Lack of scientific equipment can be directly traced to weak producers. The R&D sector is a small user: it consumes 4.5% of all instruments and means of automation used in the economy.[8] Its priority is, apparently, low. Demand for some types of instruments is satisfied by 35% only.[9] Production of research equipment lags behind the need both in volume and in the avail-

---

[5]Bratchikov, 1986; Il'ichev, 1986.

[6]Korolev, 1984.

[7]"Rech' tovarishcha Sozinova", 1986.

[8]Beshelev and Gurvich, 1986, p. 104.

[9]Korolev, 1984.

ability of a number of instruments. Scientific equipment is currently produced by more than 40 ministries.[10]

Only 30-35% of equipment needs of NII and KB are being supplied by specialized producers. A large part of the equipment is produced in-house by experimental and testing facilities of R&D institutions, which are not intended for this purpose.[11] The best conditions for the production of scientific instruments are said to exist in the Ministry of instruments, computers, and means of control (specialized producer of insturments); Union Academy (which has long been producing instruments for own needs), and four military machinebuilding ministries: radio, means of communication, electronics, and shipbuilding.[12]

12.2 Expenditures on non-labor inputs.

To get at investment and current purchases of equipment and materials, we subtract wages paid to R&D personnel from the total R&D expenditures (see Table 12-1).

In 1950, R&D funds were spent mostly on wages. Over the 1950s, the share of non-wage expenditures doubled, from 20 to 40%. It gained a further ten percentage points in the 1960s, remained nearly constant over the 1970s, and again increased in 1982-4.

---

[10]Efimov, et al., 1985, pp. 51-2.

[11]Kushlin, 1986, p. 232.

[12]Efimov, et al., 1985, pp. 51-2.

Table 12-1. Non-wage science expenditures.

Year	Structure of R&D expenditures, shares, %%		Non-wage expenditures per employee	
	Wage	Non-wage	thousand rubles	growth rate, %
1950	79.68	20.32	0.28	
1960	56.52	43.48	0.96	
1961	56.42	43.58	0.98	1.41
1962	55.21	44.79	1.05	7.92
1963	53.79	46.21	1.13	7.44
1964	52.44	47.56	1.22	7.80
1965	52.77	47.23	1.24	1.83
1966	52.01	47.99	1.31	5.77
1967	50.88	49.12	1.41	7.63
1968	51.55	48.45	1.46	3.20
1969	49.77	50.23	1.61	10.10
1970	45.43	54.57	1.97	22.79
1971	43.88	56.12	2.16	9.66
1972	42.41	57.59	2.34	8.22
1973	42.05	57.95	2.44	4.10
1974	43.00	57.00	2.43	-0.07
1975	43.95	56.05	2.57	5.72
1976	42.29	57.71	2.65	2.83
1977	42.79	57.21	2.64	-0.32
1978	42.96	57.04	2.71	2.56
1979	43.97	56.03	2.65	-1.90
1980	42.30	57.70	2.94	10.71
1981	42.06	57.94	3.03	3.06
1982	41.17	58.83	3.27	8.09
1983	39.45	60.55	3.58	9.23
1984	38.87	61.13	3.74	4.68
1985	38.67	61.33	3.85	1.69

Source: 1950-1967 - Trud v SSSR; 1968-1985 - NKh. Note: decline in wage fund in 1976 is due to the switch to different series for employment.

The current share of non-wage expenditures is three times what it was in 1950, or more than 60%. This is why the share of R&D expenditures in the national income has been increasing, even

though salaries in R&D have been growing slower than elsewhere.

Expenditures per R&D employee in current prices increased by more than the factor of 13 from 1951-1985. What about real expenditures? In the 1950s, when the price level was stable, non-wage expenditures per employee were increasing extremely fast (13%; see Table 12-2). There is little doubt that practically all this growth was real. In 1974-79, non-wage expenditures per employee were growing at 1.3% per year. This is at least commensurate with the rate of inflation. Real expenditures per employee in this period were declining. It is harder to reach such conclusion for other periods, especially 1966-73 and 1980-85.

Table 12-2. Non-wage expenditures per employee in R&D, average annual growth rates, %.

Period	1951-1960	1961-1965	1966-73	1974-1979	1980-1985
Growth rate	13.1	5.3	8.8	1.3	6.4

Source: Table 12-1.

We derived the wage fund from monthly wages, hence social security contributions of employers are counted in non-wage expenditures, as are business trip expenditures. Items consumed instantaneously (electricity, materials) are added with investment in buildings and equipment. Not all investment is included in non-wage expenditures on R&D: that in construction of new sectoral establishments is excluded.[13] Flows and stocks of capital items are of special interest for us, and we try to piece

[13]See Appendix A.4.

together data that can be found in the literature.

12.3 Expenditures on equipment.

Equipment purchases of existing R&D organizations are financed out of current expenditures, rather than out of investment (see Appendix A.4). Data on equipment purchases are scattered through the literature, and are often cited in imprecise, ambiguous ways, such as the following: expenditures on technical rearmament of science grow 1.21 times faster than total R&D expenditures, and 1.22 times faster than R&D employment.[14] Data on the growth of equipment purchases and material inputs purchases (a broader category including equipment) are compiled in Table 12-3; data on the changing share of equipment purchases in total epxenditures are shown in Table 12-4.

Table 12-3. Material inputs per employee in R&D, average annual growth rates, %.

Period	1966-70	1971-75	1976-80
Non-wage expenditures	9.7	6.5	2.7
Material Inputs	6.0*		
Equipment purchases	7.8****	22.0**	0.5***

* - Gliazer, 1975, p. 145. ** - Pirogov, 1983, pp. 145-6, quoting Problemy ekonomicheskogo upravleniia nauchno-issledovatel'skimi rabotami. Moscow, 1978, p. 109. *** - Pokrovskii, 1983, p. 80. **** - Gvishiani, 1973, p. 158.

Data in Table 12-3 are hard to interpret, given the ambiguity of quotations from which they are derived. Growth of equipment purchases in 1971-75 appears to be unbelievably rapid,

[14] Shcherbakov, 1975, p. 84.

given the growth of non-wage expenditures. It is surprising that equipment purchases grow more slowly than all non-wage expenditures. If data for 1976-80 are correct, equipment purchases per employee declined in real terms in this period. But the context in which these data are quoted in the source makes me suspicious of their reliability.

Data on the share of equipment in total expenditures are equally ambiguous. Data in Table 12-4 are not consistent with a data from other sources.

Table 12-4. Structure of science expenditures (excluding investment) in 1965-1968, shares, %%.

Year	wage fund	equipment purchase	capital repair of experimental-laboratory base	materials, scale models, etc.
1965	49.8	6.5	1.4	42.3
1966	49.5	6.6	1.3	42.6
1967	49.1	6.7	1.4	42.8
1968	48.0	7.7	1.5	42.8
1976		7.5		

Source: Grinchel', 1974, p. 46. 1976 - Iakhtin, 1983, p. 92, quoting Ashanina A. F. and Lachinov, Iu. N., "Problemy kompleksnogo finansirovaniia nauchno-tekhnicheskogo progressa v promyshlennosti", Finansy SSSR, 1978, no. 5, p. 23.

Thus, it is said that "expenditures on equipment constituted 7% of outlays on science in recent years, and rose to 7.8% in 1968."[15] The shares are almost identical to those in Table 12-4, but apparently they are the shares in the total expenditures, not of the total minus investment. Another source states that instruments, laboratory equipment, and computers constitute about

[15] Lebedev, 1970, p. 36.

60% of all material and technical inputs of R&D organizations.[16] This is not what Table 12-4 shows. It is said that by the end of the 1970s the share of equipment, instruments, and materials in total expenditures was up to 20%.[17] But Table 12-4 shows that it was already above 40% in the late 1960s!

Table 12-5 is consistent with Table 12-1 in that it shows a constant share of salaries in total expenditures in the late 1970s. It also indicates an increase in the share of equipment in the early 1970s, and its near stability in the late 1970s. Consistency of the data in Table 12-5 with those in Table 12-4 is hard to check, for they appear to relate to different totals (with and without investment).

Table 12-5. Change in the share of equipment and salary in total R&D expenditures (1970 = 1)

	1975	1980
Equipment	1.11	1.13
Salary	0.94	0.94

Source: Pokrovskii, 1983, p. 49.

Data on equipment purchases in the academies are also are not without contradictions (see columns 1 and 2 in Table 12-6). It appears that equipment purchases have increased in the Union Academy in 1966-75 much faster than total expenditures and wages. Interestingly, R&D expenditures (covering purchase of materials,

---

[16]beshelev and Gurvich, 1986, p. 104.

[17]Pirogov, 1983, pp. 145-6, quoting Problemy ekonomicheskogo upravleniia nauchno-issledovatel'skimi rabotami. Moscow, 1978, p. 109.

chemicals, production of mockups, experimental stands, testing prototypes, etc.[18]) increased even faster than equipment.

Table 12-6. Growth of expenditures in the Union Academy, 1966-1975, %.

	USSR		SOAN
	1	2	3
Total	270	250	212
Wages	200	140	176
R&D	405		246
Equipment	375	740	237

1, 3 - Chemodanov, 1978a, p. 114; 2 - Pirogov, 1983, pp. 145-6, quoting Problemy ekonomicheskogo upravleniia nauchno-issledovatel'skimi rabotami. Moscow, 1978, p. 109.

If these data are correct, equipment purchases per employee in the Union Academy must have increased in nominal terms in 1977-75.

In the Ukrainian Academy, equipment purchases growth lagged behind that of total expenditures in 1971-75, and outpaced it only by a small margin in 1976-80 (see Table 12-7). Decline in the share of equipment purchases caused concern, as did slow growth in office space (9.4%, probably over 1976-80), which was already in short supply.[19] A similar decline in the share of equipment in total purchases occurred in the Bielorussian academy, from 20% in 1970 to less than 15% in 1983 (see table 12-9).

The share of equipment purchases of the Academies is higher

---

[18]Nedil'ko, 1985, p. 81.

[19]Marushchak and Iakovlev, 1984, p. 12.

than average (compare Tables 12-4 and 12-8). For sectoral R&D in industry this share is much lower than average, 3.5%.[20] This could mean that the Academies are better equipped than sectoral R&D.

Table 12-7. Expenditures and their structure in Ukrainian Academy, growth, %.

	1975/1971	1980/1975
Total expenditures	37.9	53.3
including: budget	3.5	27.4
contract	152.3	207.7
Equipment purchase (item 12)	33.1	66.4
including: budget	4.1	67.1
contract	103.7	65.6
Share of equipment purchases in total expenditures	49.0	-30.3

Source: Marushchak and Iakovlev, 1984, p. 12.

Table 12-8. Structure of expenditures in the Union Academy, shares, %%.

	1966		1975	
Wages	49.8		39.4	
R&D	17.2		25.8	
Equipment	13.7	8.8*	22.0	18.0*
Other	19.3		12.8	
SOAN:				
Wages	44.3		36.6	
R&D	27.2		31.5	
Equipment	10.9		15.3	
Other	17.6		16.6	

Sources: Chemodanov, 1978a, p. 115. * - Pirogov, 1983, pp. 145-6, quoting Problemy ekonomicheskogo upravleniia nauchno-issledovatel'skimi rabotami. Moscow, 1978, p. 109.

In 49 sectoral research organizations in Minsk in 1983, the share of equipment purchases in total expenditures was only 10.1%

[20] Lakhtin, 1983, p. 93.

(while the share of wages was 46.1%).[21] Data for the Union Academy (Table 12-8) show that the share of equipment increased significantly in 1966-75. Ukrainian and Bielorussian data indicate that the increase in the share of equipment was going on for 20 or 25 years (1951-70 or 1975). Equipment purchases per employee in Ukrainian Academy grew by 12% a year in the 1950s, but hardly increased in the early 1960s.[22]

Table 12-9. Structure of expenditures in Ukrainian and Bielorussian Academies, shares, %%.

Ukraine:	1950	1960	1964	1967	1970	1975	1980	1983
Basic wages	59.0	47.5	44.5	44.9				
R&D	15.0	25.9	28.5					
Equipment purchases	7.0	14.7	14.5					
Other	19.0	12.0	12.5					
Bielorussia:								
Wages		58.4	53.0		39.2	33.5	29.3	28.2
R&D		16.2	22.5		24.7	35.8	47.9	46.3
Equipment purchases		9.7	7.5		20.4	15.3	12.1	14.9
Other		15.7	17.0		15.7	5.4	10.7	10.6

Source: Dobrov et al., 1969, p. 14.

There is a dependence between the sources and uses of funds. In Bielorussian academy, wages make up almost 50% of budget allocations, and only 11% of contract funds. This is because the contracts restrict the share that can go to wages; instability of

[21] Nedil'ko, 1985, p. 81-5.

[22] Dobrov, et al., 1969, p. 94.

contracts makes managers enlist their employees into budget-financed projects. The largest item in contract work is "R&D expenditures", which mostly represent payments for the work of the academy design and experimental production organizations. This is the fastest growing item, which reflects the shift towards more applied work (and more contracting).[23]

If anything at all can be concluded from the data in this section, it is that equipment purchases per employee grew fast in 1951-75 in money terms. Their rates of growth were high enough to suggest that real purchases per employee also increased. In 1976-80, equipment purchases per employee grew very slowly, and real purchases per employee probably declined. This picture broadly corresponds to the one presented in section 12-2.

The structure of the R&D sector has been shifting towards natural and technical sciences (see Chapter 14). These sectors

Table 12-10. Shares of different fields in total equipment purchases in Ukrainian Academy, %%, 1960-1965.

Field	1960	1961	1962	1963	1964	1965
Physics, mathematics, & technical	78.9	77.8	81.0	80.0	74.7	74.9
Chemical	6.8	8.9	9.1	10.0	11.7	11.8
Biological	10.9	10.8	8.7	9.4	12.8	12.5
Social	1.8	1.3	0.6	0.4	0.4	0.4
Other	1.6	1.2	0.6	0.2	0.4	0.4

Source: Dobrov, et al., 1969, p. 95.

require more equipment per employee than humanities and social sciences (see Table 12-10). Complexity and the volume of

[23]Nedil'ko, 1985, p. 81-5.

equipment required for a researcher was also increasing. An increase in equipment purchases per employee would have been needed just to keep pace with these changes. From the available data, it is impossible to say whether this was in fact accomplished.

12.4 Investment in R&D.

Data on the growth of investment (Table 12-11) were reconstructed from three ambiguous sources, and may have different coverage and price base. If they are consistent, however, they show very fast growth of investment in the crucial period of expansion of R&D, 1959-66. It is well above the 9.4% annual rate of increase of employment.

Table 12-11. Investment in R&D.

	1959		1966		1970		1985
Volume, bill. rubles	0.5		1.2		1.58		3.8
Average annual growth rate, %		13.3		5.5		6.0	

Sources: Kushlin, 1976, p. 82; Zhamin, 1971, p. 34; Ryzhkov, 1986, p. 8.

And this is still a non-inflationary period, so that nominal growth rates need not be adjusted. The rate of growth of investment in the late 1960s is only one percentage point above that of employment. Since inflation in investment accelerated in this period, real investment per employee of R&D probably declined in the late 1960s. However, after 1970, investment grows at a rate twice as high than employment (6% vs 2.8% per annum).

The share of equipment in investment has been increasing (see Table 12-12). This means that buildings of research institutes contain more instruments, apparatus, and other hardware that makes research more productive. (Also, the price inflation rate may have been higher for equipment than for construction). The share of investment going to experimental and pilot production facilities has also been increasing (Table 12-13), making it easier to produce prototypes of new machines. Both these trends are beneficial for R&D productivity.

Table 12-12. Technological structure of R&D investment, shares, %.

Year	1959	1969	1975	1976	1977	1978	1979	1980
Equipment	24	39	45	46	54	60	62	
Construction	69	54						

Sources: 1959, 1969 - Shcherbakov, 1975, p. 84: 1975-79- Pokrovskii, 1983, p. 50.

Table 12-13. Share of experimental and testing facilities in R&D investment, %.

1960	1965	1970		1975	1980
30	32	38	45*	37	40

Source: Pokrovskii, 1983, p. 50. * - Kushlin, 1976, p. 82.

In the investment for Union Academy, the share going to unique projects for physics and astronomy rose from 15-17% of the Academy's investment in 1946-55 to 36% around 1970.[24] This

[24]Mikhnevich, 1974, p. 38, quoting S. I. Kirichenko, "Upravlenie razvitiem material'no-tekhnicheskoi bazy poiskovykh issledovanii kak elementa sistemy "nauka-proizvodstvo", in: Sbornik no. 6 materialov Vtoroi vsesoiuznoi nauchno-tekhnicheskoi konfe-

suggests that though investment has been growing at healthy rates, an increasing share of it was going to things like huge telescopes or cyclotrons, which are utilized only by a small proportion of researchers. However, we lack data to check this hypothesis.

12.5 Fixed capital in R&D.

12.5.1 Stock of capital.

Table 12-14 contains data on total capital stock and its part that is most important for our purposes: scientific instruments and equipment.[25]

Table 12-14. Fixed capital stock: structure and volume.

	Jan. 1 1972 (1)	mid-1970s (2)	mid-1970s (4)	1976 (3)	mid-1980s (4)
Capital stock, bill. rubles				30	30
Equipment stock, bill. rubles		4	7.5		
Equipment as a share of total capital stock, %	40				50

Sources: 1 - Palterovich, 1979. 2 - Blyakhman, 1979, p. 58. 3- Kosov, 1983, p. 37. 4 - Beshelev and Gurvich, 1986, p. 104.

Dealing with data on capital stock is every bit as frustrating as dealing with data on flows. Data from different sources seem to be inconsistent with each other. As was the case with invest-

---

rentsii, pp. 279-80.

[25]Stock of instruments and scientific equipment excludes unique installations and complexes. Reporting on the value of instruments and equipment per scientific worker and on the share of research hardware in fixed capital started in 1974 (Blyakhman, 1979, p. 58).

ment, we are not told anything about the price base or method of accounting for the stock of capital.

Data in Table 12-14 are also inconsistent with data in Table 12-15. Yet the latter have the advantage of coming form a single source, and one hopes, are at least internally consistent. We analyze these data using the ratios in Table 12-16.

Table 12-15. Fixed capital in science and science services.

Year	Fixed capital stock on Jan. 1	Gross additions	Retired capital (full value)	Fixed capital stock on Dec. 31
1960	2.89	0.51	0.07	3.33
1961	3.33	0.57	0.09	3.84
1962	3.84	0.76	0.13	4.65
1963	4.65	0.73	0.11	5.28
1964	5.28	0.81	0.14	5.81
1965	5.81	0.86	0.17	6.54
1966	6.54	0.82	0.13	7.23
1967	7.23	0.89	0.19	7.92
1968	7.92	0.83	0.17	8.58
1969	8.58	0.86	0.15	9.21
1970	9.21	1.19	0.19	10.30
1971	10.30	1.39	0.35	11.45
1972	11.45	1.44	0.24	12.71
1973	13.44	1.52	0.26	14.79

Source: Rutgaizer, 1975, p. 142. Number for Jan. 1, 1973 is after revaluation.

Data in Table 12-16 show very fast (double-digit) growth of capital stock in 1961-73. Capital stock per employee grows at 6% per year.[26]

The rate of retirement of capital is extremely low. Based

[26]According to another source, the capital/labor ratio in re- search and design organizations increased even faster: by 291.4% in 1960-68 (Shcherbakov, 1982, p. 166). Coverage may differ from that of the data in Table 12-16.

on the average rate in 1968-73, the expected life of capital was 45 years. If 60% of capital stock consisted of buildings (see Table 12-14) with a life of 50 years, then equipment and instruments were kept on the books for almost 40 years. If the average share of buildings in the capital stock in 1968-73 was 70%, then equipment was kept in the stock for 25 years; if, in addition, the useful life of buildigns is 60 years, then equipment is kept on the books for the average of 7.5 years.

It has been found that scientific equipment becomes obsolete in 2-7 years, giving the average period before obsolescence at 5 years.[27] A study of the stock of instruments in R&D organizations of the ministries of agriculture, ferrous metals, instruments, and chemical industry in 1964-71 found the rate of renewal to be 0.12, and the average age of stock ranging from 5.1 to 6.4 years. 17.5% of stock of instruments were older than 10 years, and 27.8% were 5-10 years old.[28] This is quite consistent with the picture in Table 12-16. Capital stock growth is exaggerated because too little goes to replacement of old, obsolete equipment. Useless items are kept on the books, inflating the total stock.

Table 12-16. Fixed capital stock in science and science services: growth and structure.

Year	Rate of growth, %	Rate of retire-ment, %	Capital/labor ratio thousand rubles	Capital/labor ratio growth rate, %

[27]Volovich, 1975, p. 53.

[28]Goloshchapov, 1974, p. 22.

1960	15.22	2.42	1.76	
1961	15.32	2.70	1.78	1.06
1962	21.09	3.39	1.92	7.60
1963	13.55	2.37	2.09	9.21
1964	10.04	2.65	2.22	6.00
1965	12.56	2.93	2.35	5.93
1966	10.55	1.99	2.51	6.78
1967	9.54	2.63	2.66	5.81
1968	8.33	2.15	2.76	3.81
1969	7.34	1.75	2.84	3.06
1970	11.83	2.06	3.01	5.94
1971	11.17	3.40	3.22	6.99
1972	11.00	2.10	3.41	5.75
1973	10.04	1.93	3.78	10.87

Source: Table 12-15.

For the years after 1973, we have two partial data sets on capital stock. One derives from a study of research and design organizations in several mining and manufacturing sector ministries.[29] While the choice of establishments was random, the sample is quite large: these organizations had 200,000 employees and over 1 billion rubles of fixed capital. The rate of growth of fixed capital in these organizations in 1971-80 was lower than in all R&D in 1961-73: 9.9% per annum against 12.6%. But it was quite close to the rate of growth for all R&D in 1964-73 (10.2%). Growth of capital stock slows down over the 1970s. The rate of retirement is much higher than in Table 12-16: it averages 6.1% over the 1970s. This still too low given the weight of particular types of capital in the total stock of organizations in this study. The authors of the study estimate that an 8% retirement rate is needed if scientific instruments are to be renewed every 5-6 years.

[29]Iakhtin, 1983, pp. 90-2.

The stock of equipment and instruments grew faster than the total stock, at 12.2% a year, and the share of equipment in capital stock increased from 52% in 1970 to 66.3% in 1980. The share of computers alone increased from 7.3% to 21.3%, due to the annual growth of stock of computers of 26%. Fixed capital per employee grew at 5.7% a year, and stock of equipment per employee at 7.1% during the 1970s.

Data for the Ukrainian Academy show quite similar rates of growth of equipment stock per employee: 6.5% in 1971-75 and 5% in 1976-80.[30]

Growth of capital stock and stock of instruments in the late 1970s is faster than that of non-wage expenditures and equipment purchases. A slowdown in the growth of flows takes time to influence growth of stocks. We would conjecture that growth of capital stock in R&D slowed down further in the early 1980s.

12.5.2 Services of capital.

Hardware that has been entered on the balance sheet of a research organization does not necessarily help conduct research. We already mentioned the high rate of obsolescence of research equipment and low rate of retirement. An instrument or apparatus may be obsolete and therefore unusable, though it balloons the volume of capital per employee. It may be broken, worn down, or lack materials with which to work, and still be kept on the balance sheet. Many research needs are for sporadic use of dif-

[30]Marushchak and Iakovlev, 1984, p. 12.

ferent types of equipment. An instrument that is used once in three months is counted as a full-time part of capital stock. Research organizations, as all Soviet organizations, hoard equipment: it comes free, and may be useful someday. All these phenomena do occur.

A study of the stock of instruments in R&D organizations of the ministries of agriculture, ferrous metals, instruments, and chemical industry in 1964-71 found that 10% were not utilized at all, and 30% were utilized less than six months per year. The causes of not utilizing instruments were: change of research topic, 50%; worn down, 20%; obsolescense, 15%, and 20% were hoarded by the owner.[31] There are large above-normal inventories of instruments and materials in R&D organizations.[32]

Diversion of experimental, testing, and pilot production capacities to current production, analyzed above, also causes the shortfall in services of capital relative to its stock.

Redistribution of equipment among research establishments takes place mostly within ministries (ministries are hoarders, too). The idea of selling unneeded equipment arouses little interest in research organizations, because of the structure of their incentives. Rent of scientific equipment by the State supply commission outlets is said to cover only 10-15% of demand. There are also rental services provided internally by ministries

---

[31]Goloshchapov, et al., 1974, p. 22.

[32]Iampol'skii, 1984, pp. 45-6.

and academies, also on an insufficient scale.[33]

12.6 Summary.

Evidence presented in 8.4.1.2 and in 12.1 demonstrates that Soviet researchers are poorly equipped, sometimes lacking any means of carrying out their work. This is one of the causes of the low level of R&D productivity, and a major direction for potential improvement in productivity. This chapter attempted to find out whether researchers are now equipped better or worse than thirty years ago.

Though employment in R&D has been growing fast, equipment purchases, investment, and capital stock has been growing even faster. The question is, has it been enough to improve productivity of researchers? Some growth in capital per employee was necessary to accomodate the growing share of employees in equipment-hungry technical sciences. The standard of what represents adequate equipment was shifting, with more and better hardware required for research to proceed.

Growth in real capital per employee after 1965 was more modest than the data show, because of accelerated price inflation. In fact, real purchases of equipment and investment per employee may have stopped growing or declined in the late 1970s.

Increases in capital services may have been even smaller than increases in real capital stock. Some of the increase in capital stock represented accumulation of obsolete and worn down

[33] Lakhtin, 1983, p. 102.

equipment, or equipment hoarded without regard for the needs of research. No discount is made for equipment that is used only sporadically. Large amounts of capital were in fact used for current production, and not research. An increasing share of capital went to large installations that serve only a few researchers.

With all these influences, we cannot rule out the possibility that capital services did not keep pace with increasing requirements of modern research, at leat in some sectors.

Chapter 13. Problems of slow growth.

Many of the causes of the R&D productivity decline that have been analyzed so far are related to the rapid expansion of the R&D sector. Ministries, local authorities, and directors of institutes can indulge in bureaucratic expansionism only when the volume of resources allocated to R&D also expands. Significant shifts in resource allocation among the three systems of R&D, such as those that occurred in the late 1950s-early 1960s, also would have been impossible without rapid growth in the total volume of available resources (so that no one's allocations are cut). Accretion of bureaucratic controls is a response to the problem of managing the ever-growing task of R&D. Finally, if real capital stock per researcher declined, this must have been due to the exceedingly rapid expansion of the number of researchers. Since expansion of the R&D sector slowed down significantly in the 1970s and 1980s (see Table 1-1), the impact of these factors must have weakened.

The new condition - slow growth of inputs into R&D - interacts with the systemic feature of low mobility of resources to depress R&D productivity. Low mobility of resources is caused by the organization of R&D, and takes the forms of low mobility of funds among projects and directions of research (section 13.1); low vertical mobility of peronnel in R&D organizations (section 13.2); and low territorial mobility of researchers.[1]

---

[1] Kugel', 1972.

13.1 Ossification of the resarch agenda.

Soviet researchers in established institutes tend to persist in conducting the same project or line of research for very long periods (see 3.5.3). Some projects have long gestation periods or require long preparation or data gathering; the ability to persevere with such projects is beneficial for R&D productivity.[2] Yet in Soviet R&D, persistence is a universal phenomenon, not limited to the areas where it makes sense. Some projects or whole schools of research turn out to be barren; others are superceded by the latest results, or prove to be less productive than an alternative projects. A bias toward persistence will keep these projects alive for a long time. Resources are tied up in less promising projects at the expense of more promising ones. The only way to launch work on a new topic is to organize a new R&D establishment, since existing ones will not give up their projects.[3]

This is less of a problem when the R&D sector is rapidly expanding. After old topics receive the funds necessary to maintain them, a sizable residual can still go to establish new institutes, departments, and sectors to pursue new directions of research. When the inflow of resources into R&D slowed down in the 1970s, opportunities for starting up new organizational units

---

[2]Gustafson (1980) notes that Soviet science is comparatively strong in the areas where persistence pays off.

[3]See Gustafson, 1980.

declined, and initiation of new projects and directions of research must have declined accordingly. Fewer promising directions of research were undertaken to balance the barren and obsolete ones which already had an institutional base.

Any scientific or technical idea yields pregressively smaller results after a certain point of development yields progressively smaller results. It is well-known that successive models of machines based on the same theoretical principle yield progressively smaller improvements in productivity, until the absolute limit is reached. The progress of knowledge and technology continues because new principles and ideas are introduced. The productivity of older schools of research declines, and the overall productivity of R&D can be maintained only by the start-up of new schools. Slowdown of the inflow of resources in the 1970s and 1980s, coupled with a very weak mechanism for reallocation of resources from the old schools to the new ones, meant that total R&D productivity became dominated by that of the older schools, with their diminishing returns.

13.2 Aging of researchers.

Soviet experts on science policy express concern about the aging of researchers.[4] It has been found that productivity of a scientist increases in the early part of his career, peaks in the late 30s and early 40s, and then declines. There may be another

[4]Shchelishch, 1981, pp. 83, 86; Bogaev and Saveliev, 1982, p. 58; "Pochemu stareiut ...", 1985; Arakelian and Gubarev, 1986; "Kliuchevaia rol' ...", 1986a.

peak later in the career, but it reflects summation and generalization of earlier achievements, rather than generation of new ideas, as is the case with the first peak.[5]

Aging of the whole population of scientists would cause the share of the researchers with low and declining productivity to increase. The aggregate productivity of R&D will decline as a result. The average age of researchers depends on the pace of expansion of the R&D sector. When employment is increasing, it is mainly on account of entry level (hence, young) personnel; average age declines, and productivity increases, ceteris paribus. When growth of the sector slows down, this means that the influx of younger people becomes smaller. The average age then starts to increase. If the aging of the research agenda under the conditions of slow growth of R&D is caused by specific Soviet circumstances, the aging of researchers is, on the other hand, a universal phenomenon.

As one would expect, the age distribution of researchers in the 1960s was quite favorable. Among the employees of research establishments, the share of those younger than 30 declined through the 1960s, the share of 30-40-year-old increased, and the share of those over 40 declined (see Table 13-1). The largest cohort of researchers, those who were hired in the late 1950s-early 1960s while in their 20s, was aging and swelling the ranks of the 30-40 group. Among the science workers teaching in higher learning institutions, the share of those younger than 40

[5]See Fox, 1983, pp. 289-291 for review of the evidence.

increased from 48.9% in 1959 to 52.5% in 1970. In the early 1970s, the share of the 30-40-year-olds continued to grow, and those of the youngest and oldest (over 50) researchers to decline.

Table 13-1. Changes in age distribution of science workers, shares, %%, 1959.

Age group	-29	30-39	40-49	50-
1959:				
R&D managers	15.7	31.6	28.9	23.8
Science workers (w/o teachers)	28.0	34.4	19.6	18.0
VUZy teachers	13.3	35.6	24.5	26.6
Science workers, 1966	23.0	41.1	20.6	15.3
1970:				
Science workers, R&D managers (w/o teachers)	18.7	44.4	22.7	14.1
VUZy teachers	15.5	37.0	28.1	19.4
Science workers, 1972	16.3	46.3	24.7	12.7
Science workers in SOAN 1976	11.6			10.8

Sources: 1959 - TsSU, 1962, p. 140; 1970 - TsSU, 1973, p. 456; 1966, 1972 - Shchelishch, 1981, p. 84.

Table 13-2. Changes in age distribution of doctors and candidates of science, shares, %.

	-40	41-50	51-
doctors			
1966		18.7	75.8
1972		31.7	62.9
candidates 1966	40		

Note: * - 1966; Sources: Sominskii and Torf, 1972, p. 42; Kugel', 1974, p. 288.

Doctors of science as a group also became younger in the late 1960s-early 1970s (see Table 13-2).

Data on the average age of science workers, available only for the Union Academy, show a decline in the late 1950s and stability over the 1960s. The average age of candidates of science in the Ukrainian Academy declined in the late 1960s, as the recruits of the late 1950s-early 1960s were defending their dissertations (see Table 13-4). Since the total number of science workers expanded more rapidly than that in the Academy (see Table 8-1), the decline in the average age for all science workers must have been even more pronounced.

Table 13-3. Average age of researchers in the Union Academy, years.

	1955	1960	early 1970	1976	1978
Science workers	41.5	38	38		
in social sciences			44.4		
in Siberian Division				37	38.6
Candidates			40.8		
Doctors			56		

Sources: Bliakhman, 1979, p. 84; Dobrov et al., 1969, p. 51; SOAN - Shchelishch, 1981, p. 34.

Data on the age of researchers after 1972 are even scarcer. But the developments are not hard to figure out. People who were recruited in the era of expansion make up the single largest age cohort of researchers: almost half of science workers in 1972 were between the ages of 30 and 40. As they become older, the age distribution will become more and more skewed to the right (in the absence of a purge of oldtimers or renewed expansion).

The Siberian Division of the Union Academy was formed in the late 1950s-early 1960s, and therefore had (and probably still has) an average age of science workers that is lower than that of Academy as a whole (see Table 13-3). Data for the Siberian Division in the 1970s show a further decline in the share of science workers younger than 30 (Table 13-1), and an increase in the average age from 1976-78 by 1.5 years (Table 13-3). A similar trend is observed in the Ukrainian Academy in the 1970s among all science workers and candidates of science (see Table 13-4). The number of department heads younger than 40 in the Ukrainian Academy declined in the 1970s, and even graduate students became older: 40% are now over 28.[6]

Table 13-4. Aging of researchers in Ukrainian Academy.

		share younger than 30, %	average age
all science workers	1970		38.0
	1971	16.5	
	1977	15.4	
	1980		40.5
candidates of science	mid-1960s		40.0
	1970		39.6
	1971	6.3	
	1977	3.6	
	1980		42.9
doctors of science	mid-1960s	0.0	53.7
	1970s	0.0	

Sources: Marushchak and Iakovlev, 1984, p. 10; mid-1960s - Dobrov et al., 1969, p. 52.

Laboratories, departments, and institutes have a strong

[6]Marushchak and Iakovlev, 1984, p. 10.

hierarchical structure: bosses determine the direction of research and deploy resources, and the rank-and-file researchers execute their bosses' program. Vertical mobility within organizations is very slow (see 3.4.2). This means that the age of the people in the administrative positions matters more than that of rank-and-file researchers: it is the bosses' ideas that are being researched. A survey of Leningrad scientists engaged in fundamental research showed that ability to choose one's research project increases monotonically and significantly with age (Table 13-5). Age matters in the choice of projects, because it correlates with the position occupied by a researcher: bosses are older than subordinates.

Table 13-5. Age and ability to choose one's projects, rated on 1 to 7 scale.

Age	Sample average	25-30	30-35	35-40	40-45	45-50	50-55	55-60	60-65
Score	5.3	3.7	4.7	4.8	5.5	5.6	5.8	6.0	6.0

Source: Kugel', 1974, p. 286.

It appears that the average age of the very top personnel has been growing even when the average age of researchers was declining. From 1939-66, the average age of full members of the Union Academy increased by 6 years, and of corresponding members, by 5 years.[7] But in the recent years, this process has accelerated. In 1976-85, the share of doctors of science younger than

[7]Sominskii and Torf, 1972, p. 42.

40 declined by factor of 3, and of Academy members younger than 50, by factor of 7.[8] A 66-year-old member of the Estonian Academy recalls that scientists of his generation (apparently, in the late 1940s) were becoming candidates, doctors, laboratory chiefs and directors at age 25-30. In the 1980s, the average age of directors of academic institutes is 55-60.[9]

Soviet researchers as a group were becoming younger from the late 1950s up through the early 1970s. After that, their average age started to increase. The initial influx of young researchers may have lowered average productivity. But as the cohort recruited in the late 1950s-early 1960s was nearing its most productive age (40), it was bound to increase the average productivity through the 1960s and early 1970s. Even as the average age of researchers increased through the 1970s, it still remained close to the peak age for an individual. The real problems with productivity could not have started before the 1980s, when the largest cohort exceeded its most productive age. These problems will mount with passing of time, until the retirement of this cohort in the 1990s. The age of researchers was not a cause of the decline in productivity in the past, with the possible exception of late 1950s-early 1960s. Rather, it was a countervailing force, pushing productivity higher. However, this positive role is probably now over, and a significant negative impact of age on productivity is looming ahead. The aging of scientists

[8]"Kliuchevaia rol' ...", 1986a.

[9]Gukasov, 1984.

in managerial positions may have been more pronounced in the past, retarding overall productivity, but there is little evidence on that.

Chapter 14. Countervailing trends.

Investigating the causes of productivity decline, we have already found factors that were working in the opposite direction, at least for a part of the period with which we are concerned. The age of researchers, analyzed in the preceding chapter, is one such factor. Since our study of capital in R&D in Chapter 12 was inconclusive, we cannot rule out that the researchers have become better equipped over time, i. e., that changes in capital services were counteracting the decline in productivity. In this chapter, we discuss other factors that have pushed R&D productivity (measured or real) upwards in the last 35 years.

14.1 Declining share of higher learning institutions.

I maintain that one of the chief causes of decline in R&D productivity has been the increasing share of sectoral R&D in total R&D resources (see Chapter 8). Sectoral R&D expanded faster than the more productive Academy, and also received more resources than ministries could wisely use. The structural shift in favor of sectoral science also led to a decline in the share of higher learning institutions (see Table 8-1). Soviet experts and officials constantly complain about low productivity of scientists working in higher learning institutions.[10] *If indeed* teaching institutions have lower R&D productivity than sectoral

[10] See July 1955 Plenum of the CC of CPSU for the earlier complaints, and Gorbachev's speech at the 27th Party Congress in 1986 for the later ones.

science, then shrinking of the former's share of resources should have been beneficial for aggregate R&D productivity.

It is difficult to establish just how productive researchers at higher learning institutions are; data available in the literature vary widely (Table 14-1). It is surprising that there is no agreement on the share of science workers in higher learning in- stitutions, for TsSU has definite data on the subject (see Appen-dix A.2). Data on the share of R&D work performed at teaching institutions vary, because they are based on estimates.

Table 14-1. Estimates of the higher learning institutions' share of science workers and R&D work performed in the late 1970s-early 1980s, %.

Source code	1	2	3	4	5	6
Science workers	33	40			>35	
R&D work	15	5	6.5	<10	<10	12-15

Sources: 1 - Mavliutov, 1984; 2 - Shcherbakov, 1982, p. 28; 3-Byk, 1981, p. 7; 4 - Obraztsov, 1986, p. 3; 5 - "Glavnyi... ", 1986 and "Politicheskii ...", 1986; 6 - Kushlin, 1986, p. 222.

The volume of R&D work performed is measured as the amount of R&D funds spent (see 3.5.2). The volume of budget financing for specialized R&D units of higher learning institutions, and of contract research, are readily available; estimates of 5-6.5% share are apparently based on these data.[11] But they do not account for research performed on the funds of the education budget.[12] No statistics are reported on this research, and its

[11]One source reports a 4% share of R&D, apparently, for the early 1970s (Taksir, 1974, p. 55).

[12]See Appendix A.3.

volume has to be estimated. I think that a 35% share of science workers and a 10% share of R&D are the best estimates.

This does not necessarily mean that science workers at teaching institutions are less productive than their colleagues in other R&D systems (28% of average productivity), as Soviet officials usually imply.

Most science workers at higher learning institutions simply do not perform research. Teaching and research have been separated by institutional design. Teachers are supposed to teach and research to be performed at NIIs. The system of planning and financing teaching institutions is different from that of R&D organizations (the former are in the "education" part of the plan).[13] College teachers (in Soviet terminology, scientific-pedagogical personnel of higher learning institutions) are, as a rule, much less engaged in research than their Western colleagues, or their Soviet colleagues in research institutions. High teaching loads is one reason for this.[14] According to one estimate, over 60% of science workers in higher learning institutions do not do any research (in terms of full-time equivalents; see Appendix A.6). This means that 13% of science workers doing research in higher learning institutions perform 10% of all R&D. These numbers imply productivity that is 75% of the average, rather than 28%.

---

[13]Sominskii, 1986, p. 8.

[14]Lakhtin, 1983, p. 70; " .. these are not scientists, but exhausted higher school teachers .." Sokolov, 1985.

But even this interpretation is not correct. Research at higher learning institutions has a different structure than in the other systems of R&D; *it costs less money per researcher*. Higher learning institutions have much smaller experimental and pilot production facilities than other systems of R&D. The Ministry of Higher Education of the Russian republic, with an R&D volume of 650 million rubles, has experimental facilities with an output of 20 million rubles. This compares to the Ukrainian Academy, with an R&D volume of 260 million rubles and experimental facilities output of 240 million rubles.[15] Lack of equipment has to do not only with lack of funds, but also with absence of own instrument-making capacity. Academy of Sciences has long been manufacturing scientific instruments for its own use; Ministry of Higher Education simply does not have such plants.[16] There are more support personnel per researcher in the Ukrainian Academy than in teaching institutions.[17]

If researchers in teaching insitutions engaged primarily in fundamental research, they would be able to be highly productive with relatively small number of support personnel and little equipment. However, as we shall see, most of what these researchers are doing is applied R&D for the industry, the kind of work that requires heavy expenditures per researcher in order to bear fruit. Researchers in the insitutions of higher learning are not

[15] Obraztsov, 1986, p. 11.

[16] Logunov, 1985.

[17] Byk, 1974, p. 30.

as well equipped for this kind of research as their colleagues, and are likely to be less productive.

Poor equipment and heavy teaching loads influence the selection of new entrants in the occupation. Research-oriented young people tend to take jobs that stress research; teaching positions are occupied by people with less than the highest ability and interest in research. According to one sociological survey, 34-39% of teaching personnel engage in research because they enjoy it; 61-66% do research because they have to.[18] It is not hard to conclude that the quality of research in higher learning institutions is lower than in the Union Academy and the stronger republican academies. It is not clear how it compares to productivity in sectoral R&D.

We have only one piece of evidence on the R&D ouput of teaching institutions. In 1971-5, teaching insituttions received more than 33,000 thousand inventor's certificates.[19] This is 15.6% of the total number of inventors' certificates granted in this period. If we agree with the estimate that the full-time equivalent of 13% of all science workers perform research in teaching institutions, and if this number applies to early 1970s, then their inventive productivity is higher than average for all science workers! Though there are no data, I would assume that productivity of R&D in teaching institutions in terms of prototypes of new machines is lower than in sectoral institutes, for

[18] Kugel', 1983, pp. 182-3.

[19] And about 1100 patents. Poshekhonov, 1978, p. 25.

lack of design, experimental and pilot production units. If this is so, it means that contraction of the share of R&D resources going to higher learning institutions was beneficial for the production of prototypes, and detrimental for inventive activity.

While the share of science workers at higher learning institutions has been nearly constant in the last 20 years, their share of R&D financing has been increasing since 1970 (see somewhat contradictory data in Table 14-2). But this does not necessarily mean that the share of research performed has also increased. What seems to be happening is that research in formal R&D units on funds specifically allocated under the R&D budget, or contracts, substitutes for research performed in the departments on funds of the education budget. The share of projects performed under individual and departamental plans of R&D in Ukrainian teaching institutions declined from 96% in 1966 to 34.4% in 1975.[20]

Table 14-2. Research performed at teaching institutions.

Volume of financing, mill. rubles							Increase, times ()-all R&D financing	
1970	1971	1975	1971-75	1978?	1980	1985	1985/1975	1975/1970
583	647	1166	3500	1250	1200	2682	2.3 (1.5)	2 (1.5)

Sources: Ieliutin, 1986, pp. 62-3; Shcherbakov, 1975, p. 45; Obraztsov, 1981; Khodyrev, 1973, p. 126. Poshekhonov, 1978, p. 25.

The number of R&D units within teaching institutions has been increasing rapidly. The number of sectoral laboratories has

[20] Byk, 1981, p. 8.

almost doubled, and 120 problem laboratories were opened between 1976-85.[21]

14.2 Increasing share of technical sciences.

Many of the scientific disciplines do not produce prototypes of machines or patentable inventions. If the share of such disciplines in the total has been increasing over time, this should have caused a decline in aggregate measured productivity in terms of these output. But it turns out that the disciplines that produce the most patents and prototypes have been expanding faster than the total R&D.

All prototypes of machines are produced in the institutions of "technical", or applied sciences. (The name of a technical science is usually formed by adding the word "technical" or "technological" to the name of a science: chemical-technological sciences; technical physics).[22] Science workers in technical sciences also produce more patents than their colleagues in the other disciplines. A survey of 30 institutes of the Ukrainian academy found that the average number of patents per science worker in 1966-76 was 0.01 in geological institutes, 0.02 in biological institutes, 0.12 in physics, and 0.26 in technical sciences. Technical sciences institutes are not only more productive of patents than the others; their productivity also grows

[21]Ieliutin, 1986, pp. 62-3.

[22]Bol'shaia ..., 1974, p. 330.

much faster.23

Science workers in technical sciences hare been the largest and the fastest-growing group. Their share in the total rose from one third in the late 1950s to 47% in 1974 (see Table 14-1). Physics and mathematics lay the foundations for technical sciences. Physicists and mathematicians were the second largest group of science workers, a group also growing faster than the total. The share of physicists and mathematicians increased from 8% of the total in 1958 to 10% in 1974. (This share marginally declined from 1972-4.)

Table 14-3. Structure of science workers by field, shares, %.

Year	physics/ mathematics	chemistry	biology	geology/ mineral.	technical	agriculture/veterinary
1950	6.27	7.97	5.30	2.23	25.53	8.68
1958	7.94	7.12	4.64	2.88	32.44	6.56
1959	8.01	7.33	4.39	2.90	34.50	6.52
1960	8.18	7.41	4.26	3.01	36.66	5.98
1961	8.69	7.99	4.00	2.97	37.57	5.88
1963	9.70	5.09	4.22	2.67	43.37	4.95
1964	9.56	5.17	4.20	2.52	44.00	4.76
1965	9.61	5.05	4.07	2.47	44.96	4.60
1967	10.01	5.06	4.13	2.39	44.19	4.15
1968	10.08	5.07	4.14	2.34	44.11	4.05
1969	10.07	4.98	4.12	2.22	44.25	3.94
1970	10.27	4.94	4.03	2.19	44.14	3.82
1971	10.34	4.78	3.95	2.12	44.90	3.72
1972	10.05	4.72	3.96	2.12	45.93	3.66
1973	10.01	4.68	3.92	2.11	46.43	3.59
1974	9.99	4.59	3.89	2.09	46.85	3.57

Source: NKh.

[23]Yankevich, 1982.

The shares of science workers in all other scientific disciplines (chemistry, biology, geology and mineralogy, agriculture and veterinary science, medicine and pharmacology) declined. The same is true for social sciences (with the exception of economics) and humanities. This decline in the shares occurred despite the fast growth of each group, and because the two largest groups were growing even faster than almost all the others. Over the 14-year period, the number of science workers in technical sciences and in physics and mathematics increased more than five-fold, while in biology and geology it more than tripled, and doubled in chemistry, agriculture and medicine.

Table 14-3 continued.

Year	history/ philosophy	econom.	philo- logy	geogra- phy	law	peda- gogy	medical/ pharmacy
1950	6.85	2.82	8.37	1.58	0.64	5.43	13.21
1958	6.02	4.09	6.94	1.34	0.68	4.49	10.44
1959	5.64	3.94	6.29	1.25	0.68	4.23	10.00
1960	5.60	3.92	6.00	1.21	0.64	3.98	9.08
1961	5.24	4.03	6.01	1.13	0.59	3.90	8.47
1963	4.35	4.30	5.76	0.96	0.52	3.53	6.11
1964	4.35	4.54	5.68	0.91	0.50	3.47	5.74
1965	4.22	4.62	5.59	0.88	0.49	3.38	5.52
1967	4.19	5.52	5.48	0.82	0.49	3.46	5.40
1968	4.15	5.68	5.37	0.81	0.50	3.57	5.42
1969	4.06	6.00	5.22	0.78	0.50	3.43	5.40
1970	4.01	6.20	5.25	0.78	0.51	3.37	5.39
1971	3.91	6.54	4.96	0.77	0.51	3.23	5.26
1972	3.87	6.62	4.68	0.74	0.51	2.82	5.22
1973	3.82	6.72	4.53	0.74	0.52	2.64	5.11
1974	3.74	6.85	4.41	0.71	0.54	2.58	5.04

Table 14-3. Continued.

Year	arts	architec-ture	psycho-logy	other
1950	2.42	0.48		2.19
1958	1.55	0.40		2.46
1959	1.55	0.43		2.34
1961	1.55	0.41		1.58
1963	1.40	0.32		2.76
1964	1.35	0.29		3.02
1965	1.25	0.30		2.98
1967	1.27	0.30		3.15
1968	1.28	0.29		3.14
1969	1.29	0.28	0.16	3.30
1970	1.31	0.28	0.21	3.31
1971	1.26	0.28	0.21	3.27
1972	1.27	0.28	0.23	3.31
1973	1.24	0.28	0.23	3.43
1974	1.24	0.28	0.24	3.38

Arts, architecture, and law more than tripled, but these were initially, and still remain, very small groups. Larger fields, such as history and philosophy, philology, geography, and pedagogy more than doubled. The true explosion came in economics, with number of science workers increasing more than sevenfold.

Science workers hare progressively became concentrated in the fields that produce the outputs we are concerned with: models of new equipment and patents. This trend must have increased the measured productivity of R&D.

14.3 Increase in educational level.

In the late 1950s, only one out of five R&D employees had

higher education; persons with higher and special secondary education accounted for a bit more than a third of the total; every fifth employee of the R&D sector had less than 7 years of school (see Table 14-4). People with a high school education or less predominated, making up more than a half of the total. The share of people with higher education in science and supporting services in 1959 was twice that of those in design and the rest of the R&D sector, while the share of all other educational groups was smaller, especially that of employees with less 7 years of school. Still, every sixth employee in science and auxiliary organizations had that low an educational level.

Table 14-4. Education of employed in science and science services, shares, %%, 1959.

	Higher	Higher unfinished & special secondary	Secondary & unfinished secondary	Elementary & unfinished 7-years
Total	21.3	16.3	34.6	20.1
Science	27.5	15.2	32.0	16.9
Design	14.6	17.6	37.4	23.6

Source: TsSU, 1962, p. 124. "Science" includes auxiliary organizations rendering services to scientific organizations. "Design" includes design and project-design organizations outside of construction, geological survey, hydrometeorological service.

Over the 1960s and 1970s, the educational level of R&D personnel greatly increased. The share of R&D employees with higher education doubled, to 40% in 1983, while the share of employees with special secondary education remained nearly stable (see Table 14-5). The share of employees with high school education or less shrank correspondingly, though it did not dip below 50% until 1976.

Table 14-5. Education of R&D employees, shares, %%.

Year	Higher	Special secondary	Both	Neither
1958	21.30	16.30	36.60	63.40
1960	23.00	13.06	36.06	63.94
1965			37.33	62.67
1966	25.65	13.35	39.00	61.00
1970	28.73	14.14	42.52	57.48
1975			48.38	51.62
1977	37.26	15.55	52.81	47.19
1980	38.27	16.17	54.50	45.50
1983	40.22	15.45	55.67	44.33

Source: NKh. The share of employees without higher or special secondary education is calculated as residual. Data for higher and special secondary education in 1960 and 1970 are from Narodnoe obrazovanie, 1971, p. 237; for 1970, they do not add up to the total from NKh.

The increase in the educational level gave R&D institutions better prepared, hence more productive, scientists, engineers, and technicians. Eyewitness account of a sectoral NII in the 1960s confirmsthat younger personnel were more competent than the older, who started their careers in the 1930s and 1940s, and often had inferior education.[24] The increase in the educational level of personnel counteracted the decline in productivity.

Numbers in Table 14-5 reflect not only the influx of better educated entrants, but also several other, less beneficial processes. The educational level in the "science" subsector of R&D

[24] Agursky, 1976, p. 43.

is higher than average for the sector (Table 14-4). Since the "science" subsector was growing faster than the rest of R&D, this should have pushed the average level of education higher. Faster expansion of research compared with development was not good for R&D productivity (see 9.5.1). On the other hand, faster expansion of R&D activities than non-R&D activities classified as R&D (and likely having peronnel with a lower educational level) pushed measured R&D productivity upward (see 14.5 below).

Changes in the educational level also reflect adverse changes in occupational structure. R&D employees with higher education are managers, scientists, and engineers; those with special secondary education are technicians; and those with high school and less, manual workers. A variety of causes led to a decline in the support personnel per scientist and engineer (see 9.5.2). While lowering productivity of scientists, this trend also pushed educational level upward. Indeed, problems with support personnel indicate that the R&D sector is already saturated with scientists and engineers; an increase in the number of support staff would now boost productivity, while lowering the average level of education.

14.4 Increase in the importation of knowledge.

An important input into the national R&D effort is knowledge aquired from abroad (2.2). The volume of this input appears to have greatly increased over the last 35 years. In the early 1950s, the Soviet Union was fairly isolated from the West;

machinery imports, purchase of licenses and trips by scientists were all at minimal level. All these channels for importation of knowledge have greatly expanded since then. The purchase of licences was virtually non-existent before 1965; a few hundred were purchased in the late 1960-1970s.[25] The volume of machinery imports from the West increased by more than 15 times (and more than doubled during the 1970s only).[26] (Of course, the amount of knowledge imported is not proportionate to the volume or value of machinery inputs: ten units embody as much knowledge as just one.[27]) Scholarly exchanges also became much more widespread in the 1960s and 1970s.

It is impossible to say whether productivity of this particular input declined or not. But an increase in the import of foreign knowledge should have increased the observed productivity of domestic inputs.

The Soviets have argued recently that imported technology serves as a substitute for domestically produced technology. The import of technology in the 1970s took the pressure off the R&D sector; instead of demanding new technology from domestic providers, ministries imported it. R&D organizations have been demoralized by the ease with which superior technology can be obtained abroad. Import also provided an alternative to financ-

[25] Hanson, 1982, p. 431.

[26] *Ibid.*, p. 450; 1982a, p. 135.

[27] *Ibid.*, 1982, p. 418.

ing the full spectrum of research directions.[28] If this is so, increased imports of hardware and (possibly) licenses have retarded R&D productivity. I doubt that such arguments have much merit; they reflect special interests of the R&D bureaucrats jealous of import competition.

14.5 Non-R&D components of R&D have been growing slower than R&D proper.

Our measures of R&D inputs are defined much more broadly than measures of output. Moreover, some people who are not even supposed to produce inventions, machine prototypes, or any other new knowledge are counted as R&D personnel. If the number of these people grew faster than that of R&D personnel in proper sense, this could have accounted for some decline in measured R&D productivity.

Table 14-6. Employment in science and science services by subsector, shares of the total, %%.

Year	Research, design, & services organizations	Geological survey	Hydrometeoro-logical
1950	61.20	34.31	4.48
1955	59.88	35.89	4.23
1960	75.27	21.78	2.95
1961	78.77	18.50	2.73
1962	80.39	17.04	2.58
1963	80.89	16.58	2.53
1964	81.38	16.18	2.44
1965	82.29	15.39	2.32
1966	82.96	14.81	2.23
1967	83.57	14.30	2.13

Source: TsSU, 1968, pp. 24-5.

[28] "Rech' tovarishcha Aleksandrova A. P.", 1986; "Ob osnovnykh ..", 1986.

Available data show the opposite trend. Growth of R&D employment occurred mainly in R&D proper, not in the geological survey or the hydrometeorological service, whose employees are also counted in the total (see Table 14-6). This trend should have boosted measured R&D productivity in 1950-67, as fewer and fewer irrelevant elements were included in R&D input measure.

14.6 Shift to more applied research.

Trends in resource allocation among the stages of R&D are hard to quantify (see Appendix A.6), but it has been observed that both sectoral and academic R&D is becoming progressively more applied (see 8.4.2.1 and Chapter 10). Research in teaching institutions undegoes the same metamorphosis. The volume of budget financing of basic research has been maintained on the same level for a long time.[29] At the same time, contract research expanded and now accounts for almost 90% of R&D in higher education (see Table 14-7; excluding R&D conducted with non-R&D funds.) In the case of poorly equipped scientists in higher learnign institutions, possibilities for buying equipment out of contract funds may have especially strong appeal.[30] Is this process beneficial or harmful for productivity?

We do not measure directly the output of basic research. It is captured only to the degree that it gives rise to new inventions and new machines. If resources that go towards the

[29] Ieliutin, 1986, pp. 64, 66.

[30] Andriushchenko, 1984.

acquisition of new scientific knowledge in basic research are reallocated to applied research and development, this should result in a greater number of inventions and prototypes per unit of input, because more resources would flow to the activities that directly produce these outputs. This is why we classify the shift to more applied projects as a countervailing factor.

Table 14-7. Contract financing of R&D in higher learning institutions, %.

Increase in volume, times		Share in total R&D financing, %	
1961-1969	1961-1970	1970	1985
almost 10	almost 2	82	88

Taksir, 1974, p. 55; Ieliutin, 1970, p. 11; Khodyrev, 1973, p. 126; Ieliutin, 1986, pp. 64.

The increase in measured productivity arising from increasing share of applied research may correspond to a real improvement in R&D productivity, if previously there had been a relative hypertrophy of basic research. It may also be detrimental for "true" R&D productivity, by undermining its scientific base, but could still boost the measured productivity in the short run. In our case, the increase in applied projects comes through the increased share of projects ordered by the enterprises and ministries, through contracts or other means. These organizations are not interested in radical innovations (or often in any innovations at all). They tend to order small improvements of existing technologies that often border on trivial. This was documented in 8.4.2.1 and Chapter 10 for sectoral science and the

academies. But situation is even more critical in higher learning institutions, where the share of contract research is the greatest. Concern about small-scale, trivial projects performed under these contracts is voiced regularly in discussions of this system of R&D.[31] In the early 1908, 500,000 science workers in teaching institutions were performing 100,000 projects.[32] Since the full-time equivalent of science workers doing research is at best one third of their number, this leaves less than 2 researchers per project (under the conditions of lack of support personnel).[33]

Being indifferent to how their R&D funds are being spent, customers of contract research would even condone fraud on the part of R&D organizations.[34] Therefore, the increasingly applied nature of R&D in this case is detrimental for "true" R&D productivity, though it is beneficial for the indicators which we can measure.

---

[31]See, e. g., Taksir, 1974, p. 55; Andriushchenko, 1985, Mavliutov, 1984.

[32]Mavliutov, 1984.

[33]Andriushchenko, 1985, speaks of only 20% of time being left for research, and of doing contract projects regular hours.

[34]On fraudulent research performed by a teaching institution under contract with enterprises, see Gladkov, 1987.

PART IV. POLICIES AND PROSPECTS.

The Soviet economy is now at a critical juncture. Its performance has sunk below the level acceptable to the political leadership. The current leader is committed to improving performance, even at the cost of politically risky moves. Increasing R&D productivity is at the core of this task. A flurry of reform and policy changes in this area was announced in 1985-86. We analyze these reforms in Chapter 15. The interaction of the likely effects of reforms with the causes of the slowdown and countervailing forces will determine the future course of R&D productivity, to be discussed in Chapter 16.

Chapter 15. Gorbachev's reforms for R&D sector.

15.1 Soviet awareness of problems in R&D.

Intelligent reforms and policy changes are possible only on the basis of an understanding of the problems to solved. The analysis of the problems of R&D sector has long been more open than that of the economy as a whole. All important determinants of decline in R&D productivity have been mentioned in the press. Some of the relations between R&D performance and the economic system have also been pointed out.

Low productivity is mentioned quite often in the official documents and pronouncements on R&D in sectoral ministries and

higher learning institutions.[1] Many publications on sectoral R&D in 1986 spoke also about declining productivity. Trivial and fake projects, paper pushing, and spinning wheels in sectoral R&D were mentioned by Prime Minister N. Ryzhkov.[2] Expansionism, poor equipment, and aging of personnel were mentioned by Ie. Ligachev, member of Politbureau and Secretary of the Central Committee of the party.[3] Inflexibility in the choice of projects was mentioned by the Vice President of the Union Academy V. Kotel'nikov.[4] The corroding role of the economic mechanism, with customers of R&D being indifferent to innovation, is also mentioned (e. g., by Vashchenko, member of the GKNT collegium).[5] Ministries are being roundly criticised for irresponsible management of R&D. Soviet officials are well aware of the processes going on in R&D, of their immediate causes, and underlying determinants in the economic system.

15.2 Greater allocation of resources and more flexibility in their use.

The most important new policy with respect to R&D is quite simple: to increase the share of resources going to this sector.

---

[1]See Council of Ministers decree "V Sovete Ministrov ..", 1986 and Pravda editorial "Ekonomicheskie rychagi ...", 1986.

[2]Ryzhkov, 1986, p. 8.

[3]"Kliuchevaia ...", 1986a.

[4]Ibid.

[5]Vashchenko, 1986.

15.2.1 Increasing expenditures and investment.

As early as 1971, Soviet authors were emphasizing the necessity to stabilize the share of resources allocated to R&D, and to try to get more out of these resources.[6] Stabilization in the size of the R&D sector relative to the economy (and, possibly, even in absolute terms) was viewed as a normal process common to all developed countries, and even hailed as a sign of the switch from the extensive to the intensive mode of the growth of science.[7] The share of resources going to R&D indeed stabilized in the 1980s (see table 1-2), and I wonder how many of the experts arguing in favor of stabilization of this share were simply repeating the official line.[8]

One no longer hears such expert opinions after 1985. Economists writing about R&D now advocate massive redistribution of resources in favor of R&D.[9] This, of course, coincides with the shift in official priorities, as reflected in the 12th five-year plan.[10]

The rate of growth of R&D expenditures planned for 1986-90 is significantly higher than in the past decade (see Table 15-1).

---

[6] Gliazer, 1971.

[7] Pokrovskii, 1983, p. 48; Iuzefovich, 1980, p. 34-5.

[8] Shchelishch, 1981, 79-80; Kosov, 1983.

[9] Anchishkin, 1986, pp. 12-13.

[10] For another instance of an abrupt shift of published expert opinion coinciding with the shift in official policy, see Kontoro- vich, 1985a, p. 27, footnote 43.

It is also higher than the planned rate of growth of national income utilized, 4.1%.[11] Hence, the share of R&D expenditures in national income is to increase from 5% in 1985 to 5.7% in 1990.

Table 15-1. Planned growth of R&D expenditures.

	Volume, bill. rubles		Average annual growth rate, %			
Year	1985	1990	1971-75	1976-1985	1971-85	1986-90
Expenditures	28.6	39.5	8.3	5.1	6.1	6.7
Current	24.8	33.0			6.2	5.9
Investment	3.8	6.5			6.0	11.2

Source: Ryzhkov, 1986, p. 8; NKh-85; Table 12-11.

If accomplished, this will be an unprecedented jump in the share of the sector, especially given the comparatively low rate of growth of national income (see Table 1-2 for historic shares).

Increased expenditures will go first of all to investment and equipment purchase. Strengthening the "material-technical base" of science is one of the main direction of official policy for the next five years.[12] The planned rate of growth of investment is high both by historical standards and compared to any concievable rate of inflation in investment, so that the real volume of investment should certainly increase.

Investment data in table 15-1 cover only construction and equipment of new facilities in non-sectoral R&D (see Appendix A.3). I do not believe that creation of a significant number of new R&D organizations is planned for 1986-90. Hence, the

---

[11]Ryzhkov, 1986, p. 7.

[12]"Politicheskii doklad ....", 1986.

increase in investment will go towards new facilities for "homeless" academic institutes (see 12.1), and for construction of testing, experimental, and pilot production facilities for the Academies and, to a smaller degree, for higher education institutions (see 15.5). It appears that great hopes invested in the increased role of the Academies in innovation (see 15.3 below) are supported by generous planned investment allocations.

For 1986-90, radical improvements in experimental facilities of sectoral R&D are also planned. A revision of sectoral plans that continued to slight investment in these projects was ordered.[13] Construction and reconstruction of experimental and testing facilities will be given the highest priority for inclusion in annual and five-year plans.[14]

If carried out, these plans will no doubt increase the productivity of R&D. What is the likelihood that they will came to pass? R&D expenditures and investment targets are part of a plan that is generally considered too optimistic. In particular, its investment program is judged to be inconsistent with other parts of the plan.[15] If the plan begins to unravel, some parts of investment program will be sacrificed, and R&D investment may be one of them. Industrial ministries will be trying to cut investment no matter what happens to the overall investment program. Output targets for ministries are high, and new production

---

[13]Silaev, 1986.

[14]"V Tsentral'nom ...", 1986.

[15]Noren, 1986.

capacity can relieve pressure on existing plants. The attempts to divert R&D investment funds or investment goods and services to production capacity projects are a constant of ministerial behavior, and that will be stronger now because of higher growth targets. Council of Ministers counteraction to such behavior may also be stronger now than in previous years, but it cannot be totally effective.

Planned growth of current expenditures is somewhat below the average for 1971-1985 (see (Table 15-1). It will financ the purchases of equipment and materials and some inevitable expansion of employment. According to the plan, the output of instruments for science will double in 1986-90.[16] (MNTK for scientific instruments, a joint venture of the instrument-producing arm of the Union Academy and Ministry of Instruments and Computers, is planning to produce 300 million rubles of instruments in 1990.[17])

15.2.2 Making remuneration of scientists and engineers more flexible.

The remuneration structure of researchers and designers in R&D institutions and industry is being reformed, starting in 1986.[18] R&D organizations are allowed to use savings of the planned salary fund to augment the salaries of existing workers.

---

[16] "Rech' tovarishcha Shkabardni", 1986.

[17] Tarasov, 1986a.

[18] "V TsK KPSS ...", 1985.

Savings are achieved through the release of personnel, or through abolishing vacancies. The remaining employees have to carry heavier workload, but their salaries also increase. This innovation involves several new rights given to the managers of R&D organizations or units:

a. the right to fire or demote poor performers in the process of "certification" (conducted at least every five years);

b. the right to retain a fixed proportion of savings against the planned volume of salaries; the latter is fixed over a long period of time (5 years), rather than adjusted annually to actual level of staffing;

c. the right to use savings for adjusting salaries of employees. This includes two provisions:

- awarding supplemental pay for work on especially complex or important projects, up to 50% of base salary; or supplemental pay to highly qualified specialists of up to 30% of base salary. These supplements should be reduced or withdrawn for poor performance.
- base salary can be changed according to the results of certification or for good performance within the limits established for given position, disregarding targets for average salary for given position.

It is expected that 6-10% of researchers and designers will be released in the course of salary restructuring.[19]

The reform decree incorporates the features of the Leningrad

[19]Kharin, 1986.

experiment with remuneration of engineers and designers. In this experiment, redundant specialists were transferred to blue collar positions within the same institutions, or found employment at establishments with traditional system of remuneration. An experiment which also involved the salaries of managers of design and engineering units was conducted in Ul'ianovsk.[20] Output norms for designers were introduced and remuneration adjusted according to performance relative to these norms.[21] The Leningrad experiment resulted in a 10% reduction in the number of designers, and an even greater increase in the productivity of those who remained. The pay of designers caught up with that of workers (though not in all cases).[22]

However, this appears to have been a one-shot effect. Once the most obvious savings in the frozen wage fund are made, remuneration cannot grow any further.[23] There are also problems with the quality of design. Quantitative output norms are necessarily crude, based on density of lines on the drawings, and ignoring originality, convenience for the users, and other crucial characteristics of a product.[24] This put the best designers at a disadvantage, and many of them left the organizations that conducted the experiment. It also created an incen-

---

[20]Nikitin, 1986.

[21]E. g., Denisov, 1985.

[22]Nikitin, 1986.

[23]Foniakov, 1984; Denisov, 1985; Nikitin, 1986.

[24]Foniakov, 1984, Nikitin, 1986.

tive for well qualified designers to do routine work such as detailed drawings. The incentives favored those who can do routine work fast. The number of rationalization proposals from the designers involved in experiment declined.[25]

The fixed total volume of salaries is the important weakness of the reform. After the worst workers are fired, and part of their salaries redistributed among the better workers (assuming this does take place), the only way to reward the best will be by taking from the good, not a viable option.[26]

A more fundamental weakness is the absence of compelling reasons for the managers to use their new rights.[27] These could have been provided only by the pressure on the whole organization to perform (e. g., threat of bankruptcy). Certification was introduced by the 1968 reform, but remained a mere formality. Now, as before, managers are very reluctant to conduct certification for real. According to a survey, only 15% of all organizations are trying to connect remuneration with individual performance. Unlike tenure decisions in American colleges, certification is conducted without any input from outside those organization. This allows managers to settle the score with troublesome employees under the guise of certification.[28] As a reflection of

---

[25]Nikitin, 1986.

[26]Pushkarev, 1986, p. 115.

[27]See the afterword to Kharin, 1986.

[28]Andreev, 1986. The article is titled: "Certification: against those who work poorly or those who do not suite their bosses?".

lack of interest in the new rights, industry has been slow in adopting the system, and has repeatedly been prodded by the leadership.[29] Implementation of the new system is mostly ritualistic. In some cases, redundancies allowed only 1.5% savings of the salary fund, and translated into an addition to salary of 3 rubles per month.[30] Salary savings in the Ministry of Instruments and Computers amounted to a few rubles per month per person.[31] This probably means that hardly anyone was made redundant, and the savings from abolished vacancies were divided equally among all employees irrespective of performance.

Finally, managers suspect that the Ministry of Finance will at some point expropriate their salary fund savings, as it did in Shchekino experiment.[32] In this case, they will be left with fewer employees and a lower salary fund.

The reform involves several other changes. Salaries are becoming more graduated within research organizations. There will be five levels for researchers, instead of three. A principal researcher has to have a doctor's degree; leading researcher has to be a doctor or a candidate; there are no degree requirements for senior researcher, researcher, or junior resear-

---

[29]"Ob osnovnykh ...", 1986; "V Tsentral'nom ...", 1986.

[30]Kostin, 1987. He also cites two institutes that increased salaries of the best employees by 50-100 rubles (a month), apparently on account of redundancies.

[31]Gorbachev, 1986; "Sovet ... ", 1986.

[32]Andreev, 1986. The article is titled: "Certification: against those who work poorly or those who do not suite their bosses?".

cher. At the same time, salaries may become less graduated across organizations, as all organizations are divided into two classes by pay level, instead of three. The role of a scientific degree in remuneration declines. It no longer entitles a science worker to an automatic sizable addition to base salary. Now, upon receiving a degree, science workers can be either be promoted or get a pay raise of up to 50 rubles per month, not to exceed the salary ceiling for given position. That is, if a science worker gets the maximum salary for his or her position, and is not promoted, then earning a degree brings no increase in pay. Alternatively, the same pay may be attained without a degree, though merit-based pay raises. A senior science worker without a degree can now earn up to 350 rubles, instead of 190 rubles under the old system.[33] The decline in the role of degrees in determining salary is beneficial, since it may increase correlation between pay and performance.[34]

Base salaries for designers are being raised as savings in the wage fund permit. The role of bonuses in stimulating scientists and engineers is increased; bonuses will be tied to the economic effect from implementation of the innovations created by them. The system of remuneration of researchers in industry and R&D sector is becoming unified.[35] There is some vague talk of

---

[33]Kharin, 1986.

[34]See Moroz, 1986, on inefficiencies generated by the crucial improtance of degree for remuneration.

[35]Kharin, 1986.

additional personnel cuts to create vacancies for younger entrants.[36]

15.2.3 Closing down institutions.

The most radical policy to improve R&D productivity would be to shut down less productive organizations, and redirect part of their financing to the more productive ones. The Soviet R&D sector should shrink, if its productivity is to increase substantially.

Over 200 institutions have been closed down, merged, or restructured over an unspecified period. If this number includes the closings and mergers of the early 1980s (see 7.1), there was not much new activity in this respect under Gorbachev. Ministries obstruct this process by ignoring the recommendations of GKNT on unproductive institutes. (GKNT itself can only investigate and submit recommendations.)[37]

Iel'tsin, a Member of Politbureau and first secretary of the Moscow city party committee, stated that out of 39 research institutes identified as "doing nothing for years", 15 will be shut down. Thirty thousand science workers who did not pass regular evaluation (attestatsiia) will be transferred to production jobs.[38] The closing down of two sectoral institutes was

---

[36] Kharin, 1986.

[37] Vashchenko, 1986.

[38] Ielstin reportedly delivered this speech on April 11, 1986 in the House of political education in Moscow, to propagandists. A genuine-looking account of the speech was published in Novoye

announced in the Council of Ministers' decree.[39]

Layoffs of R&D personnel and closings of entire institutions may serve later as a model for the economy at large. However, I have the impression that closings and restructurings are being applied sparingly. Most of the personnel of restructured institutions end up in R&D jobs elsewhere. R&D employment is not actually being shrunk, and its quality is not changing.

Researchers and designers, who are the focus of current policies, represent only a small part of all the specialists. To solve the problem of the overproduction of specialists, future policies would have to be much broader. The reform of higher education, analyzed in 15.4, will hardly contribute to a solution to this problem.

15.2.4 Supply reform.

Currently, requests for supplies for a year have to be submitted about six months before the year starts; they are arbitrarily cut and the resulting deliveries are foten delays, sent to wrong customers, etc. This system is especially damaging to R&D, since there is more uncertainty about exact future needs in this sector than in the others. Rationing encourages inflation of requests and hoarding, and thus gives rise to shortages.

Starting in 1987, R&D sector will be transfered to wholesale trade in producer goods. Supplies will be bought from the regi-

---

Russkoye Slovo, Aug. 1, 1986.

[39]"V Sovete Ministrov ...", 1986.

onal administration of Gossnab on short notice.[40] This should encourage more efficient use of materials and instruments, discourage hoarding, and increase productivity of material inputs (see 12.5.2). However, the success and the scope of the introduction of wholesale trade is one of the greatest unknowns of Gorbachev reforms. First of all, it can work only for mass-produced, commodity-type inputs, not for custom-made goods or ones produced in small batches. Second, it appears that widespread wholesale trade will conflict with centralized planning of production, and therefore cannot exist in the Soviet economy as it is currently constituted.

15.3 New (and not so new) organizational forms.

Some of the current reforms of R&D will merely continue changes initiated in the previous decades. In 1985-7, R&D organizations in agriculture, construction, transport, communications, geology, and supply will be transfered to khozraschet system of creation of new technology.[41] Its effects were analyzed in 9.3.1. The use of goal-oriented programs will be widened. Starting with 1986, there will be a hierarchy of Union, republican, sectoral, and regional programs and programs of territorial-production complexes. Some of the financing of Union programs will be carried out from the special fund of GKNT,

---

[40] "Snabzheniu ...", 1986.

[41] "V Tsentral'nom ... ", 1983.

created from levies of EFRNTs of Union ministries.[42] This may make programs somewhat more effective than earlier (see 9.3.2).

15.3.1 Associations (POs) and science-production associations (NPOs).

Mergers of sectoral R&D organizations with production enterprises is now seen as a cure for the problems of sectoral R&D.[43] This newest reform has a venerable history by now. Mergers of several industrial enterprises, sometimes including R&D units, appeared in the late 1960s and were promoted through the 1970s. Some R&D organizations are merged into production associations (POs), where they just serve the needs of the plants in the association, much as plant-level units do (see 3.2.2). More important are science-production associations (NPOs), where the R&D unit plays a leading role.[44] NPOs are intended for speeding up development of new products by uniting applied research, development, testing, and pilot production under one management. Products developed by NPOs are to be transferred to regular enterprises or POs for mass production.

The number of NPOs increased from just a few in the late 1960s to about 100 in the end of 1975.[45] In 1986, there were 350

---

[42] "V Tsentral'nom ...", 1983.

[43] Vashchenko, 1986.

[44] See Cooper, 1982, pp. 456-462, and Cocks, 1983.

[45] Gliazer, 1979, p. 29.

NPOs, which absorbed 544 NII and KB.[46] In machinebuilding, most R&D institutions (75-80% of all R&D employment), except for the leading sectoral institutes, have been merged into production or sicence-production associations.[47] In the Ministry of Instruments and Computers, all R&D organizations were merged with production units.[48]

The current five-year plan (1986-90) envisions the continued merger of sectoral R&D organizations with production enterprises. Only the head institutes working on topics important for the whole sector (numbering about 500) will retain independence. Over 1000 organizations will be included into POs. About 400 research and design organizations will be merged in the planned 480 NPOs.

The main benefit claimed for mergers of R&D and production units is the speedup of development and implementation of new technologies. When research, design, testing, and production are all undertaken by independent organizations, they take place sequentially; there are long interruptions between the stages, because of the difficulties in the transfer of technology. Merger would allow these stages of R&D cycle to overlap (e. g., development starts before research ends), and therefore to shorten the time from research to actual innovation.

The drawbacks of mergers are similar to those when R&D is

---

[46]"Osnovnye ...", 1986, p. 2; Vashchenko, 1986.

[47]Silaev, 1986.

[48]"Rech' tovarishcha Shkabardni", 1986.

brouhgt under the strong influence of production. The main problem of the industrial manager is reaching his current production target. If necessary, this is done at the expense of "plant-level science". Experimental production capacities are occupied with current production, instead of development work; designers and researchers themselves are shifted to production work, because of a deficit of workers. R&D units at production enterprises have long suffered from such behavior of managers.[49] It is paradoxical that at the same time as independent R&D organizations are being merged with production plants in order to strengthen their experimental facilities, chiefs of R&D units already within production plants plead for independence exactly for the same reason.[50]

"Plant-level science" units that are classified as part of R&D (non-productive) sector are subject to staff cuts of non-productive personnel, for which plants receive regular targets. The level of wages there is also lower than in other technical units of plants.[51]

This generalization on the status of "plant level science" does not apply to the military sector, where production plants are assigned to design bureaus, and where the latter dictate to

---

[49] E. g., design bureau at Kharkov tractor plant (Kashuba, 1978); design bureau at the Urals heavy electrical machinery plant (Kostin, 1983, p. 31); also Vasil'ev, 1979.

[50] _ibid_.

[51] Natapov, 1986.

the former what to produce.[52] This practice is most visible in the aircraft industry.

R&D units merged into POs are reduced to the level of "plant science", and should experience all the effects described above. The situation with NPOs is more complex, for there, R&D units should take the lead. Past experience with NPOs indicates that the interests of current production nevertheless reassert themselves even in this organizational form. Institutes formerly subordinated to technical administrations of their ministries start taking orders from production glavks (whenever the merger is real and not perfunctory). And the latter are interested in smooth current production, oppose radical product innovations, and agree only to improvements of what is already being produced.[53] Enterprises within NPO exert similar influence on the institutes.[54] The statute of NPO envisions that after the new technology it created is fully mastered, it should be transferred to regular production plants. NPOs should not engage in series production. This is honored in the breach, with series production comprising almost all output of some NPOs.[55]

A Soviet R&D expert predicts that without radical changes in the planning of technological progress, mergers will make R&D establishments mere appendages of production units, doing trivial

---

[52]Agursky, 1976, p. 10-11.

[53]Rassokhin, 1980, p. 55.

[54]Shcherbakov, 1975, p. 113.

[55]Gliazer, 1979, p. 30.

work.[56] I agree with such a prediction. The only change that has been made so far to alleviate the pressure on R&D in NPOs was to allow some ministries to transfer some of their NPOs to the "science and science services" plan.[57] This supposedly lifts the pressure to produce regular output. However, I cannot envision massive withdrawal of production capacity at hundreds of NPOs from current production, given the output targets of the current plan.

In most cases, mergers are not fully consummated. Production plants and R&D components of NPOs are working under different and unconnected planning, financing, and incentives arrangements.[58] As a result, the merger of R&D and production units remains formal. Plans for production and R&D are often mutually inconsistent, which leads to disproportions between these two components. Since the sources of financing of R&D and production branches remain separate, it is impossible to centralize management, merge similar departments of production and R&D units, or shift personnel and wage funds from one to another. In addition, salaries of employees in analogous positions in R&D and production are different.[59] No relief for these problems is even discussed.

Associations may benefit production in the short run, but

[56] Lakhtin, 1986.

[57] "V Tsentral'nom ...", 1983.

[58] "Ekonomicheskie rychagi ..", 1986; Beliakov, 1986.

[59] Parkhomenko, 1986.

they hurt R&D, and hence, in the longer run, hurt production.

15.3.2 Intersectoral complexes and engineering centers.

A new organizational form that is promoted in the 12th five-year plan is MNTK - intersectoral science and technology complex.[60] Associations are being formed from organizations of the same ministry. But many modern technologies require cooperation of several ministries. Moreover, if fundamental research is involved, participation of the Academy of Sciences is necessary. Transfer of technology among organizations with different subordination is difficult in the Soviet economy; hence the need for a single organization to span intersectoral divisions.

More than half of MNTKs are led by the Academy institutes.[61] They also include sectoral R&D organizations. For example, one MNTK includes 29 organizations of 22 ministries and the Academy; another, 14 organizations of the Academy and of 5 ministries all over the USSR.[62] Their task is research, development, testing, small batch series production, and preparation for mass production of high tech inovations: laser-based technologies, personal computers, fiber optics, catalysts, rotor technology, scientific instruments, high temperature synthesis, genetic engineering, etc. Many MNTKs are headed by leading scientists, including full

---

[60]"Osnovnye ...", 1986, p. 2.

[61]"Kliuchevaia ...", 1986a.

[62]"MNTK - maksimum ..", 1987; "MNTK: shagi ...", 1986.

and corresponding members of the academies.[63] In the beginning of 1987, there were already over 20 MNTKs. Five-year plans of MNTKs for 1986-90 have been compiled.[64]

Whithin MNTK, a new type of unit called engineering centers is being created. They are aimed at implementation of finished projects, and work under contract with industry.[65] Engineering centers perform final stages of development and testing and manufacture and debug the prototype. They help to free researchers from these tasks.[66]

A model statute of MNTK was enacted in the summer of 1986.[67] Constituent organizations retain their subordination to the ministries, and this gives rise to a large number of problems.[68] It is not clear how to include enterprises in the work of MNTK, since they already have plans to fulfill. There are legal problems with MNTK arrangement.[69]

It was hoped that MNTK would be given high priority in supply ("will be getting everything they need as they need it"). The ability to get scarce supplies would then be used as lever

---

[63]Vashchenko, 1986.

[64]"Kliuchevaia ...", 1986a.

[65]Vashchenko, 1986.

[66]"Inzhenernyi tsentr", 1985.

[67]Tarasov, 1986a.

[68]"MNTK: shagi ...", 1986.

[69]Vasin, 1986.

with manufacturers of technologies developed by MNTK.[70] However, equipment supplies appear to be allocated to the ministries supervising the constituent units of MNTK, not to MNTK itself.[71] This allows ministries to divert supplies for their own needs.

It was similarly hoped that the head organization of MNTK would be able to finance and withdraw financing of other participants according to its needs.[72] It is not clear whether this will be the case, or whether all participants will be financed through their ministries. In the latter case, there will be little, except for plans on paper, that holds MNTK together, or gives the head organization power over the other participants.

Dissatisfaction with the work of the actual MNTK prevails. Academic institutes and enterprises which are headed by innovative and enterprising individuals, and which cooperated well before MNTK, continue to do so. But in most cases, problems of intersectoral coordination prove to be insurmountable.[73] But formation of MNTK remains the latest directive of the party, and therefore activity in this area goes on, if only perfunctorily. "The current creation of engineering centers and MNTK suffers from substitution of paper creation for the real work; it is surrounded by a huge number of various papers, forms, tables, and

[70]"Za ramkami ...", 1986.

[71]Tarasov, 1986a.

[72]"Za ramkami ...", 1986.

[73]Tarasov, 1986a; "Kliuchevaia ...", 1986a; "MNTK - maksimum ...", 198.7

unneeded bureaucratic procedures".[74]

The likely future effects of MNTK can be judged by those of recent attempts at intersectoral coordination of research and innovation: dual-subordination organizations and goal-oriented programs. Organizations with dual subordination originated in the Siberian Division of Union Academy. The Academy provided ideas and researchers, and production ministries were to build and equip R&D facilities, as well as provide auxiliary personnel for these organizations. The organizations were charged with developing ideas generated by the Academy, producing workable prototypes, and transferring the results to production plants. Ministries started to burden these organizations with routine tasks, leaving no time for developing new ideas.[75] Similar symptoms are already exhibited by the MNTK, where capacities of experimental production units are being diverted to current production.[76]

In another attempt, two intersectoral design bureaus of the Institute of Automatics of the Siberian Division were created at production plants, staffed by academy personnel, and charged with implementing the results of the institute. They were strangled by the organizational rules and procedures of industry, and enterprise management's lack of interest in innovations.[77]

---

[74] "Rech' tovarishcha Patona", 1986.

[75] Gliazer, 1979, p. 30; Lakhtin, 1986.

[76] Anchishkin, 1986, p. 12.

[77] Nesterikhin, 1986.

The Institute of Welding of the Ukrainian Academy of Sciences has long had in its subordination units for development, testing, and small scale production, and actively helped implement its results by providing consulting and trouble shooting on the spot. It serves as a model for the currently decreed MNTK - intersectoral science and technology complexes.[78] But there is an important difference in that all units of the Institute of Welding were within one administrative domain (Ukrainian Academy) and subordinated to the Institute's director.

The objective of MNTKs is the same as that of goal-oriented complex programs. The latter failed because of the impossibility of directing different participants in various ministries within one program (see 9.3.2). The same fate is likely for MNTK.[79]

One sure effect of MNTK will be to involve the Academy deeper into applied research and implementation, and increase the influence of production ministries over academic research. This is consistent with the general goals of the five-year plan, which envisions further strengthening of the technical orientation of academic institutes and formulates the tasks of the Academy with reference to technological goals.[80] It has been decided to upgrade Urals and Far Eastern filialy of the Union Academy to Divisions.[81] Most likely, they will expand, and will carry more

---

[78]"Za ramkami ...", 1986.

[79]Lakhtin, 1986.

[80]"Osnovnye ...", 1986.

[81]"Kliuchevaia ...", 1986a.

applied tasks than the Union Academy. The insufficient volume of basic research was mentioned with concern by a Politbureau member.[82] However, current reforms and plans work to diminish the volume of fundamental research even further.

15.3.3 Temporary units.

Expansionism and rigidity of Soviet R&D stems to a large degree from the necessity to form a permanent organization or department to solve any problem. Once created, these units usually do not die, whatever the fate of the original problem. One solution to that would be creation of temporary units, task forces, etc. The creation of temporary task forces for the solution of large problems has been decreed, but it progresses only slowly.[83] Temporary laboratories within R&D organizations are allowed to engage both the employees of the mother organization and outsiders. Their main task is fast implementation of developed technologies. In the Union Academy, 36 have been created as of mid-1986; and in republican academies, there are 4. Another kind of temporary organization is the intersectoral temporary scientific-technological collective, for solution of important problems. It can employ leading specialists at special ("personal") salaries. An example is "Start", a collective for the creation of 5th generation of computers.[84]

---

[82] Zaikov, 1986.

[83] Bachurin, 1985, pp.89-90.

[84] Vashchenko, 1986.

The very fact that the exact number of temporary units is known means that they remain very rare. They are hampered by the ban on holding more than one job. This means that people joining the task force will have to look for a new job after the project is completed.[85] Even the organization that serves as the model for current reforms, the Welding Institute of the Ukrainian Academy, cannot solve the problem of temporary assignment of its employees. Because of wage and financial regulations, people from different units of the institute cannot be engaged in the work of the engineering center. The director of the center cannot sign contracts and hire.[86] Current laws and the financial system do not allow for a matrix type of internal organization.

The broadening of rights of institutes, departments, and laboratories has been promised, together with those of regional units of the Union Academy and republican academies.[87] This may make them free to establish their own internal structure. But so far, no such move has been made.

15.4 Reform of higher education.

The proposed reform of higher education may influence R&D productivity indirectly, by changing the quantity and quality of young scientists and engineers on the market, and directly, by

[85]Nikitin, 1984.

[86]Gusev, 1986.

[87]"Kliuchevaia ...", 1986a.

reforming R&D in teaching institutions.[88] We will analyze the first set of proposed changes only briefly, for it involves issues transcending the limits of this report. Under the current system, employing ministries submit their requests for specialists with higher education to the planning organs, which work out the plan for teaching institutions. Employers are not repsonsible for honoring their requests, and their forecasts of future needs are widely off the mark. The centerpiece of reform is to make employers more responsible by making them order specialists from teaching institutions, and defray part of the cost of education of these specialists. Specialists will be bought by the enterprises, just as they buy materials, parts, and energy. This mode of procurement does not induce efficient use of materials, parts, and energy; I do not see why it should induce efficient use of specialists. The necessary measures for reducing the glut of specialists - closing down weak institutions and departments, and cutting down enrollments - are not mentioned in the draft reform proposal, or in the discussions in the press. I find it unlikely that these proposals will help reduce the overproduction of specialists.

An important measure that may improve the quality of new entrants into R&D is the involvement of full-time researchers in teaching. Bringing teaching insitutions into a closer contact with research and production organizations is the general aim of the proposed reform. More specifically, it was promised

---

[88] "Osnovnye napravleniia perestroiki ...", 1986.

that restrictions on part-time teaching by the Academy of Sciences researchers will be lifted.[89] This will expose students to better minds than those of their regular teachers, and introduce them to the up-to-date research problems and methods. The best teaching institutions have been attracting researchers as part-time teachers for a long time, so most improvements in quality will be felt in the second- and third-tier schools.

Reforms of research in higher education go along two main directions: levelling of organizational differences with the other two systems of R&D, and making (allowing?) teaching institutions develop, test, and even manufacture the results of research of their teachers.

Research in teaching institutions is to be financed, planned, and supplied through the same channels as sectoral and Academic R&D. This means that instead of doing research at the departmental laboratory, on funds from the education budget, and according to personal or departmental plan, college teachers will do more (or all?) research in formal R&D units attached to their colleges, on funds allocated under the R&D budget, and on projects coordinated with national and sectoral R&D plans. The change in planning is the least consequential, for reasons outlined in 3.5.3. The switch to financing from the R&D budget and supply from the same channels as R&D organizations is intended to improve equipment, but may not succeed in this goal, for now teaching institutions will compete for research funds and

[89]"Kliuchevaia .... ", 1986a.

supplies head on with more powerful sectoral and academic establishments.

Another direction of the reform is to create organizations for development, testing, pilot production, and small batch series production within higher learning institutions, their regional associations, and ministries of higher education. These are to be patterned on design-technological bureaus created at Rostov, Novocherkassk and Taganrog VUZy to develop and implement the results of research of personnel teaching there.[90] Intuition based on the realities of the market economy suggests that this is a wrong move. Colleges do not know how to manage development and production; doing so will distract them from their main tasks, teaching and research. They should transfer their results to specialized organizations. However, this would not work in the Soviet economy: there is no one interested in taking somebody else's results and developing them. The Academy of Sciences encounters overwhelming difficulties in getting sectoral R&D to develop its results (see 10.2). In Soviet conditions, developing and producing innovations internally is the best solution. In this area, higher education will be doing what academies have already been doing for some time. This will be good for the economy: it will get more innovations than otherwise. In-house testing and production facilities will also be used to produce equipment for poorly equipped reserearch laboratories of teaching institutions.

[90] "Dlia otrabotki ...", 1986.

The big question is whether all these facilities will in fact be created. The reform proposal urges ministries to help educational institutions to create testing and pilot production facilities, transfer whole plants to teaching institutions, and allow the latter to use the production capacities of the ministries for pilot production. I interpret this as a sign that no serious investment is planned for this purpose; instead, resources are to be voluntarily surrendered by the ministries. This is unlikely to occur on any significant scale, given the nature of the ministries (see 8.3) and taut targets of the 12th five-year plan.

The applied slant of research in teaching institutions is likely to become even stronger as a result of these reforms. While the proposed reform talks about doubling the volume of basic research, alongside with tripling or quadrupling the volume of development, the reform emphasizes development and implementation of innovations as the responsibilities of the teaching institutions. In the attempt to curb the worst excesses of contract work, developing contracting between the ministries of higher education and industrial ministries has been proposed. It is also proposed to include a 20% markup in contract research charges, to be utilized for equipment purchases and financing of basic research.

It is estimated that the volume of R&D in teaching institutions can be increased 2-2.5 times.[91] There is no word of lower-

[91]Obraztsov, 1986, p. 10.

ing the teaching load of existing researchers, so they will not be able to do twice as much research as now. What is going to happen is that research financed by R&D funds will replace research financed by education budget funds, that is not presently accounted for. The actual volume of research will remain the same. The productivity of R&D in teaching institutions will increase to the degree that better equipment and more support personnel will be available. Whether these improvements will be significant is doubtful, given the general economic situation.

Chapter 16. Prospects for R&D productivity.

The future course of R&D productivity will be determined by the *interaction of past trends and* current policies. Here, we try to project the future course of particular determinants of R&D productivity, and the effects of Gorbachev reforms on them.

16.1 The underlying structure.

The main villain in the story of the decline of R&D productivity is not the R&D sector itself, but the production sector. Most of R&D is applied research and development, activities directed to satisfy of the needs of the production sector. Only that sector is qualified to judge what constitutes success or failure in these areas. But production managers in the command economy fail to act as responsible users of the results of R&D. They fail to guide R&D resources to their best uses through demand for R&D results. Moreover, they tend to subvert R&D by diverting its resources and burdening it with routine tasks, and by tolerating weak, unproductive, and fraudulent projects and institutions.

Once applied R&D is so subverted that it grows unable to solve even the simplest problems, fundamental science is called upon to fill this role. This diverts the already limited resources away from basic research, and also endangers the very structure of fundamental science. It has been effective to no small degree because it has kept away from the production sector. Now

that it must play the role of applied R&D, it increasingly comes under the influences of the same forces that have trivialized applied R&D.

Debasement of sectoral R&D and the impending corruption of academic science are not the results of a policy mistake. They reflect a genuine dilemma of a command economy in the age of rapid technological progress. To benefit production, R&D has to be in close touch with it. But the incentives of production sector managers are inimical to innovation and therefore, to productive R&D. Current reforms do even more to subordinate R&D to the needs of the production sector. This will be harmful for R&D, but Soviet leaders have no choice: this is the only production sector they have.

Gorbachev's reforms do not strike at the core of the economy - command allocation of resources. Vague talk about market reform places it in the future, perhaps in the 1990s.[1] Given all the political uncertainties involved, this is the same as not considering market reform at all at present. When and if market reform becomes a more realistic prospect, it almost certainly will be a Hungarian-type reform. And the Hungarian experience suggests that this type of reform does not radically increase the production sector's interest in innovation (hence, responsibility in dealing with R&D), though it brings an improvement over condition under the command economy.[2]

---

[1]Aganbegian, 1987, p. 6.

[2]Kornai, 1986, gives a general assessment of the reform.

The ambitious output targets of the current five-year plan, coupled with the discipline drive, will force the ministries to scurry everywhere for resources, and will reinforce their usual anti-R&D behavior pattern.

With customers largely uninterested in R&D, bureaucratic rules and procedures are established as an alternative mechanism for resource allocation in this sector. But they cannot substitute for the judgment of an informed and interested user. In the best case, these bureaucratic procedures just add to the load of management and planning tasks, diverting time and energy from R&D proper. In the worst case, they further subvert R&D activity, by directing it towards routine, but easily controllable projects.

With the structure underlying poor R&D productivity intact, there is no reason to expect that this sector will radically improve its performance, as desired by the Soviet leadership. The Soviet Union is not going to join the world club of leading technological powers, and may well lose its prominent status in fundamental research. If the changes in R&D productivity are less than momentous, it is still important to know in which direction they will go. In the rest of this chapter, we review the likely future course of the determinants of R&D productivity, and their interaction with current reforms in this area.

16.2 Determinants of R&D productivity that no longer matter.

Much of the productivity decline of the past was connected with expansion of the volume of resources available to this sec-

tor. Declining productivity means that an ever larger share of resources is wasted, and it is easier to increase the degree of waste when the amount of available resources increases. To engage in expansionism, ministries and institutes must have funds and personnel limits earmarked for the creation of new organizations and departments. The increase in the share of sectoral R&D also was accomplished mostly through adding resources, not redistributing them.

The era of fast growth is over for the R&D sector, just as it is over for the economy in general. Creation of new institutes is under strict control; salary funds at existing institutions are frozen. In the long run, both the number of institutes and employment in the sector are bound to grow, because there will be need to pursue new directions of research. But this growth will be glacially slow. Therefore, expansionism and the increasing share of R&D resources of the profligate sectoral R&D, important in the past, will not significantly depress R&D productivity in the future.

The processes that caused R&D productivity to decline have been going on for several decades, and some of them have simply run their course. The share of inventions patented by individual inventors is now about 10%, and can hardly decline much more. In Chapter 8, I quoted the estimate that only 10% of work performed by sectoral R&D organizations can be characterized as research. If this estimate is reasonable, then there is not much left for sectoral production managers to subvert. Standards for presenta-

tion of drawings appear to have reached the summit of complexity and unreasonableness, and are not likely to become even more cumbersome (in fact, some improvement in this area may be expected).

Some of the factors that had been working in the opposite direction have also spent themselves. The increase in the educational level of R&D employees, which was beneficial in the 1950s and 1960s, was no longer helpful in the 1970s. The R&D sector, together with the rest of the economy, suffers from the excess of people with higher education, and shortage of workers and technicians.[3]

The increasing importation of foreign knowledge must have been very productive as the country was opening up after the isolation of the early 1950s. In the 1970s, the USSR reached the highest level of openness compatible with its political system. Further opening (e. g., the possibility for Soviet scientists and engineers to work abroad in significant numbers, and for foreigners to work in the USSR) will be beneficial for productivity of the R&D, but is incompatible with the political system. This source of increasing R&D productivity has largely been exhausted.

16.3 Determinants of R&D productivity that will be important in the future.

16.3.1 Determinants pushing R&D productivity higher.

Soviet R&D is sorely underequipped. For example, at some of the most advanced civilian enterprises, few designers have calcu-

---

[3]See Kontorovich (forthcoming).

lators, and pencils are in short supply.[4] In such conditions, more equipment may do much to improve productivity. The investment policy for 1986-90 sets out to accomplish just that. There are several considerations that make the implementation of these plans problematic. Under the conditions of ambitious and internally inconsistent plans, central authorities will be looking soon for places to pare planned investment growth. Sectoral ministries, pressed to reach their taut production targets, will search for investment resources to augment their production capacities. In both cases, R&D investment is a tempting target for cuts: current five-year plan targets will not suffer if fewer laboratory buildings are constructed and equipped.

Even more problematic is the use to which some of the newly built facilities will be put. The pressure to use experimental and pilot production plants and shops for current production will be as strong as ever. This diversion of existing capacities turns R&D investment into a bottomless pit. No matter how much one invests in experimental and pilot production plants, they are turned to other uses and R&D remains deprived of their services.

The Soviet government is aware of this problem, and issues increasingly strict rules and regulations prohibiting such diversion of investment and capacity. But such rules have been issued before, e. g., in the course of the 1968 reform, and have

[4] Nikitin, 1986.

failed.[5] The causes of diversion of investment resources and capacities from R&D to current production are still there. Investment in the facilities of the academies and higher learning institutions (i. e., what one can see in Table 15-1) is relatively safe from such diversion. However, the new policy concerning the academies and teaching institutions encourages them to go into small-scale production of new products. This may force them to follow the example of sectoral ministries, and use pilot production and testing facilities for regular production.

Mergers of R&D organizations into POs and NPOs are conceived as another way of strengthening their "material base". However, the net effects of the mergers are likely to be negative (see the next section).

Closing down the organizations and purging the ranks of researchers and engineers are the most promising policies initiated by the current leadership. These should produce an increase in R&D productivity in the short run. However, it is likely to be a one-time boost, rather than a permanent factor pushing productivity upwards. Also, the scale of these policies appears too small to have a significant impact.

The most important part of the reform of the remuneration system will be the abolition of sizable automatic pay increases for earning a scientific degree. It undermines the sources of guaranteed income unrelated to performance, and frees funds for

[5]On investment goals and safeguards of 1968 reform, see Gvishiani, 19873, pp. 160-1.

recognition of the differential productivity of researchers. Making remuneration more flexible allows managers to reward the best performers and punish the worst ones, without resorting to such a drastic measure as firing. The extent to which this new flexibility will in fact be utilized remains problematic. R&D managers with internal motivation (desire for excellence, public service) will use their new rights fully, to run their already productive units even better. These managers, however, form a minority. Most R&D managers still lack external motivation to increase the productivity of their establishments, and will not use the new rights in the intended way. Pay reform should be expected to bring only local and marginal improvement.

Raising relative salaries in R&D relies on the redistribution of the salary fund savings from redundancies. But the planned scale of redundancies (6-10%) is not enough to close the gap with other sectors, much less restore the pay differential in favor of the R&D sector that would have been justified by the much higher education level. Since release of personnel is likely to fall far short of the planned numbers, progress in this area will be small. In the long run, it is impossible to close the gap between the pay of the scientists and engineers on one hand and workers on another, as long as there is excess supply of specialists and excess demand for workers. The solution to this problem lies outside the R&D sector. To change the labor market situation, it will be necessary to pare down the number of workplaces in production, cut down enrollment in higher learning

institutions, and transfer some of the specialists into blue-collar jobs, all highly problematic and politically risky enterprises.[6]

Some positive influences represent corrections of glaring missteps of the past. Thus, some work goes on to simplify standards governing design documents and drawings, though apparently with little progress. In principle, there is no reason why the standard requirements for drawings of machines that will be produced in the quantity of one cannot be made less burdensome. The Council of Ministers has issued a decree that radically cuts down the number of approvals which designers have to obtain from third parties.[7] Not all approvals that are now abolished were purely dysfunctional and superfluous. Therefore, I do not expect this decree to be fully implemented; many approvals are bound to survive, or to reappear under a different guise. But abolition even of some approvals is going to bring much relief to designers.

The share of resources going to technical sciences will increase. This increased share will partly reflect the fact that the technical sciences are becoming increasingly more costly, and at a higher rate than social sciences and humanities. A researcher in the technical sciences needs increasingly more equipment and support personnel than his colleague in another field. But I also have the impression that the share of researchers working in the technical sciences will increase. The major push of current

---

[6] See Kontorovich (forthcoming).

[7] "Tekhnicheskaia ....", 1986.

policy is to get more modern technology quickly from R&D, and this requires stronger technical sciences. The share of technical sciences may even expand at the expense of natural sciences, as Academies become increasingly involved in applied research, and as the Division of Technical Sciences of the Union Academy is formed. This process will boost total R&D productivity, as measured in patents granted and prototypes of machines created. The diversion of resources from natural sciences in the long run may prove harmful to real R&D productivity.

16.3.2 Determinants depressing R&D productivity.

Current reforms of R&D strengthen one negative trend (subversion of R&D by the production sector) and do nothing to check two other negative trends: the aging of researchers and the aging of topics.

The role of the production sector in guiding sectoral R&D is increasing, as most R&D organizations in this system are merged with enterprises. Much of sectoral science is being reduced to the level of plant science. This means ever more trivial and minute projects, R&D personnel manning assembly lines at the end of the month, pilot production shops used to produce standard output, and guidance from production glavks of the ministry.

Since the number of independent R&D organizations has declined, monopolism of the remaining head institutes is strengthened. Policy pronouncements on restructuring sectoral R&D

reaffirm the role of head institutes.

The increasing involvement of the academies in applied research, development, and implementation of innovations will draw resources from the areas in which academies excel (fundamental research). It will also involve the academies in close cooperation with the production sector, with such attendant ill effects as trivialization of projects and diversion of resources to non-R&D uses. The excellence of the Academy has been maintained through selectivity and ethics. Expansion into the production sphere may prove destructive for both, and as a result hurt even the quality of fundamental research. The increased involvement of the Union Academy in development and implementation is good for production, but harmful for science - hence, in the longer run, harmful for production also.

Increasing the role of bonuses tied to the economic effect from implementation of innovations in remuneration of scientists and engineers also orients them toward simpler projects with shorter payoff period, and invites fraud and abuse.

In a period of slow growth, R&D productivity faces the greatest threat from the aging of research portfolios and the aging of researchers themselves. Current reforms do nothing to address these threats. No alternative mechanism for planning R&D and for redistributing resources to more productive projects has been established. Nothing is done to stop the aging of researchers. There is no mechanism for the systematic weeding out of the less able and less competent, creating vacancies for new

entrants. There is no compelling reason for R&D managers to use their current powers in this area. The recently decreed mandatory retirement for directors of institutes is not enough, for it does not address the main problem: the demographic echo of the expansion of the late 1950s-early 1960s.

16.4 Can the imitation strategy be abandoned?

So far, we have been analyzing the prospects of Soviet R&D productivity relative to its own past record: will it increase or decrease. This analysis also sheds light on the likely future performance of Soviet R&D relative to that of the developed capitalist countries.

Soviet applied research and development imitates Western results to a great degree imitating Western results. This is usually explained as a result of lower productivity and the general backwardnesss of both R&D and the production sector. As a high Soviet official put it, "'Lazy brains', lack of initiative, and minimal demands on enterprises for original products, have infrequently resulted in a proclivity to copy foreign technology. One may even encounter the following opinion of novel projects: since there is nothing like this abroad, this can hardly be of any use, it cannot work out. Some research institutes, instead of conducting advanced fundamental and applied research, just copy."[8]

---

[8] V. Trapeznikov, Pravda, March 20, 1980, quoted in: Rassokhin, 1985, p. 222.

But the argument is sometimes reversed, and the imitation strategy is blamed for backwardness. Indeed, the inflexible pursuit of imitation can freeze a country into a permanently inferior position. If this is the case in the Soviet Union, this strategy should be abandoned immediately in favor of pioneering original projects. Such a change would bring spectacular results in terms of catching up with the West. Whenever Soviet authors admit imitation (and this is not done frequently or easily), they argue that this approach should be abandoned.[9] Can it be done?

Throughout this report, I have argued that Soviet applied research and development suffers from a lack of effective control from the users of their results. The system is searching for substitutes for this control. One such substitute is direction from above and bureaucratic planning procedures. Imitation is another and a more effective means of control over domestic R&D. Western R&D is guided by demands of users whose very survival is at stake in the competitive market. By doing what Western R&D does, Soviet scientists and engineers indirectly subject themselves to the same guidance. This is not as good as the real thing, because of the built-in lag, and because the needs of Soviet markets may be quite different from those in the West. Still, imitation is the best possible strategy given the economic system. The imitation strategy cannot be abandoned before Soviet industry

[9] A series of articles on design in Sotsialisticheskaia industriia in 1986 was published under the title, and later under the rubric "To catch up? No, to surpass" (April 25 and 26, May 14).

begins to care about innovation.

16.5 Summary.

The rapid deterioration of R&D productivity was associated in the past with rapid expansion. This period is over. Indeed, past accumulation of irrationalities creates opportunities for fast improvement in some areas. Current policies and reforms try to exploit some of these opportunities. They will at least stabilize, and possibly somewhat increase, measured R&D productivity in the short run, if only through the shock of change. But the reforms do not introduce a mechanism for continuous improvement in R&D productivity. They aggravate some of the worst features of sectoral R&D, endanger the only island of excellence in the R&D sector, the Union Academy, and do little to check the two most adverse trends in R&D: the aging of researchers and the aging of the portfolio of research projects.

The short-run increase in measure R&D productivity will be achieved in part through dilution of real R&D productivity (diversion of resources from fundamental research and from long-payoff-period projects to simpler ones). Real R&D productivity will be further damaged as the aging processes slowly unfold. The long-run prospects for R&D productivity are as dim as they were before the current package of reforms was formulated. The talk of abandoning the role of the technological follower and becoming a leader will remain only talk.

APPENDIX A. Data and definitions.

A.1 Definition of R&D sector.

Organizations included in science and science services sector.[1]

i. Organizations conducting research:

- academies (excluding teaching academies), their filialy and divisions;
- research institutes (NII), their filialy and divisions (including institutes of scientific and technical information);
- computer centers which systematically conduct research;
- observatories;
- central and other independent research laboratories;
- independent design organizations, conducting project-making, design, and research;
- scientific and experimental stations which systematically conduct research according to an approved research plan;
- experimental and selection stations: agricultural, veterinary, experimental-melioration, hydrotechnical, plant protection, irrigation (dozhdeval'nye), for mechanization and electrification of agriculture, for animal husbandry (zhivotnovodcheskie), fishery, soil protection, biological, hunting, volcanological, lymnological, permafrost, industrial research;
- experimental fields, support points (opornye punkty), and experimental bases which systematically conduct research accor-

[1]Gosplan, 1974, pp. 768-770.

ding to an approved research plan;

- Union, republican, and regional archives which systematically conduct research according to an approved research plan;
- national parks and preserves, botanical and zoological gardens, dendraria, etc., which conduct research;
- museums conducting research;
- libraries and knizhnye palaty conducting research;

ii. Design and project making organizations (except for project making organizations in construction, forestry, and design organizations classified as research organizations.

iii. Experimental plants which do not produce for the outside users;

iv. Hydrometeorological service: the sector, producing hydrometeorological and environmental pollution forecasts and information;

v. Science service organizations:

- conducting long-run survey of stocks of fish, whales, sea animals and sea products;
- experimental fields, support points, experimental bases in agriculture and forestry (except those conducting research);
- laboratories for testing construction materials, normative-research stations, machine testing stations, central bureaus of technical information, state laboratories for checking

measurement instruments, computer centers of research organizations (except those conducting research), and others.

A.2 R&D employment

Soviet statistics operates with two categories of science employment, roughly similar to OECD's R&D employment and researchers.[2] Employment in science and science services includes everyone working in organizations listed in A.1.

The major omission in this category are the employees of higher learning insitutions, both members of departments (kafedra) and those working at the R&D units of teaching institutions (laboratories, bureaus). However, employees of research institutes subordinated to higher learning institutions are included in R&D employment.[3] Employees of R&D units at production enterprises are another omitted group.

Science workers is a narrower category.[4] It does not include designers and supporting personnel, only the researchers. On the other hand, some of the people counted as science workers are not R&D employees. Science workers include all persons with scientific degree and/or rank, irrespective of place or nature of their work. The great majority of such people works in research institutions, for until very recently, this was the only place were degrees and ranks were tied to higher pay. However, there

[2]Snosku na OECD.

[3]Mindeli, 1986, p. 49.

[4]See the officials definition in NKh-74, 798.

are also people working outside the R&D sector, who hold scientific degrees; they are counted as science workers, but are not counted as R&D employees. Some of these people conduct research at the non-research institutions, such as industrial ennterprises. However, the majority are probably those who aquired degrees for prestige or some other purpose, and do not conduct any research. Getting scientific degree became a fashion among Soviet officials in the 1970s.

If R&D employment concept excludes people who teach at higher learning institutions, thus underestimating the number of people doing research, science workers concept includes them without any adjustment for their heavy non-research load, and thus overestimates the number of researchers. Science workers include people without either degree or rank, who do research at R&D establishments. This category is also fully counted in R&D employment. Finally, science workers include specialists without either degree or rank, who systematically engage in research at the enterprises and project-design organization.[5] This category should also be counted in R&D employment.

"Performing research" should be understood as "engaged in the projects included into the properly approved R&D plan". Not all people engaged in such projects are counted as science workers, but only those with at least higher education; technicians, laboratory assistants, and others without higher education are

---

[5]This category was first included in 1962.

excluded.[6]

Roughly speaking, science workers without those employed in higher learning institutions and in industry, represent researchers and research managers in science and science services sector. So adjusted, the number of science workers can be legitimately compared to that of R&D employees.

The structure of science workers is known in more detail than that of R&D employment. In the officially designated scientific establishments (i. e., those listed in A.1), personnel departments have a special card for each science worker. Based on these cards, science establishments annually report to TsSU (form No. 5-NK) the number and structure of science workers by position, sex, rank and degree, nationality, and specialization.[7] The number of science workers was accounted as of Oct. 1 before 1962, and as of year-end - since 1962.[8]

A.3 Science workers: degree and rank.

Changes in structure of science workers by degree are due to the rapid expansion in the total number of science institutions in the late 1950s - early 1960s, and its aftermath (see Table A-1). The expansion was fueled by adding new personnel at the entry level. These young people were given research topics, and hence counted as science workers. Yet they were still a long way

[6]Serov, 1972, p. 46.

[7]Serov, 1972, p. 46.

[8]NKh-63, 712.

from getting their first degree. The influx of the young researchers without degree swelled the ranks of science workers, and drove down the share of science workers with degrees (see Table A-2).

Table A-1. Science workers: number and growth.

Year	Thousand persons, year-end	Growth rate, %.	Year	Thousand persons, year-end	Growth rate, %.
1950	162.51		1966	712.42	7.20
			1967	770.01	8.08
1953	191.90		1968	822.91	6.87
1954	210.20	9.54	1969	883.40	7.35
1955	223.90	6.52	1970	927.70	5.01
1956	239.88	7.14	1971	1,002.90	8.11
1957	261.60	9.05	1972	1,056.00	5.29
1958	284.04	8.58	1973	1,108.50	4.97
1959	310.02	9.15	1974	1,169.70	5.52
1960	354.16	14.24	1975	1,223.40	4.59
1961	404.13	14.11	1976	1,253.50	2.46
1962	524.50	29.79	1977	1,279.60	2.08
1963	565.96	7.90	1978	1,314.00	2.69
1964	611.96	8.13	1979	1,340.60	2.02
1965	664.58	8.60	1980	1,373.30	2.44
			1981	1,411.20	2.76
			1982	1,431.70	1.45
			1983	1,440.00	0.58
			1984	1,463.80	1.65
			1985	1,491.30	1.88

Source: Appendix C.

Share of candidates was increasing until 1956, then plummetted from 1957-1965, and has been increasing again since then, as the initial entrants started getting degrees and the growth of the total slowed down. Share of doctors of science was declining up to 1965, and very slowly increasing since then.

Table A-2. Structure of science workers by degree and rank, shares, %.

Year	By degree		By rank			
	Doctors	Candidates	Academy members, professors	Docents	SNS	MNS, assistants
1950	5.11	28.00	5.48	13.41	7.02	12.06
1953	4.43	31.01	4.43	12.87	6.72	10.32
1954	4.28	32.92	4.19	12.75	6.66	7.71
1955	4.24	34.84	4.02	12.77	6.52	7.64
1956	4.09	35.73	3.79	12.67	6.50	7.42
1957	3.82	33.33	3.59	12.08	6.38	8.14
1958	3.63	31.69	3.38	11.51	6.06	8.31
1959	3.39	30.32	3.13	11.06	5.94	8.48
1960	3.08	27.76	2.80	10.22	5.73	7.54
1961	2.80	25.36	2.55	9.45	5.20	7.10
1962	2.27	20.72	2.10	7.74	4.54	8.58
1963	2.24	20.35	2.01	7.58	4.56	8.46
1964	2.24	20.25	1.96	7.52	4.44	7.88
1965	2.23	20.22	1.88	7.31	4.32	7.36
1966	2.33	21.39	1.91	7.41	4.24	6.68
1967	2.38	21.99	1.91	7.39	4.21	6.01
1968	2.43	22.65	1.93	7.40	4.27	5.83
1969	2.47	23.25	1.91	7.35	4.22	5.48
1970	2.54	24.20	1.95	7.39	4.20	5.26
1971	2.60	24.85	1.94	7.30	4.23	4.91
1972	2.66	25.52	1.95	7.29	4.30	4.50
1973	2.69	26.01	1.95	7.26	4.31	4.25
1974	2.71	26.46	1.92	7.22	4.33	3.97
1975	2.64	26.71	1.87	7.18	4.36	3.68
1976	2.76	27.55	1.91	7.38	4.49	3.53
1977	2.81	28.01	1.98	7.55	4.63	3.38
1978	2.79	28.25	1.99	7.72	4.67	3.23
1979	2.77	28.61	2.01	7.89	4.76	3.16
1980	2.75	28.85	2.00	8.06	4.81	2.99
1981	2.74	29.03	1.99	8.20	4.86	2.85
1982	2.77	29.55	2.00	8.47	4.95	2.84
1983	2.85	30.24	2.04	8.71	5.10	2.92
1984	2.92	30.70	2.07	8.79	5.15	2.79
1985	2.97	31.08	2.08	8.84	5.20	2.66

Source: Table C-2.

Table A-3. Non-overlapping classification of science workers by rank and degree for October 1, 1956.

	Number of persons	Shares in total number of science workers, %.
Doctors, total	9761	4.07
Professors	7741	
SNS	1121	
No rank	899	
Candidates, total	85659	35.71
Professors	482	
SNS	13821	
Docents	26676	
MNS	2705	
Assistants	2074	
No rank	39901	
Rank, no degree	17693	7.38
Professors	856	
SNS	688	
Docents	3161	
MNS	9019	
Assistants	3969	
Degree, no rank	18592	17.00
Neither degree nor rank	126767	52.85

Source: NKh-56, 258.

Changes in the share of science workers with ranks bestowed by teaching institutions (professor, docent) are due to the same process just described, and also to the declining share of science workers in teaching institutions (see Table 8-1). For this reason, these shares did not show anything like a recovery of the share of candidates of science. Share of academy members and professors (which is dominated by professors) was declining until 1965, and then stabilized.[9] Share of docents was declining

[9] In 1984, professors constituted more than 91% of the joint number of professors and academy members (NKh-84, 103).

up to 1975, and only then started to grow.

Table A-4. Science workers without degree and rank.

Year	Without degree thous.	Without degree share	Without rank thous.	Without rank share
1950	108.71	66.89	100.81	62.03
1953	123.90	64.56	126.00	65.66
1954	132.00	62.80	144.40	68.70
1955	136.40	60.92	154.60	69.05
1956	144.38	60.19	166.98	69.61
1957	164.40	62.84	182.60	69.80
1958	183.74	64.69	200.94	70.74
1959	205.52	66.29	221.32	71.39
1960	244.96	69.17	261.06	73.71
1961	290.33	71.84	305.93	75.70
1962	403.90	77.01	404.10	77.04
1963	438.06	77.40	437.96	77.38
1964	474.36	77.52	478.56	78.20
1965	515.38	77.55	525.88	79.13
1966	543.42	76.28	568.22	79.76
1967	582.41	75.64	619.71	80.48
1968	616.51	74.92	663.01	80.57
1969	656.20	74.28	715.90	81.04
1970	679.60	73.26	753.20	81.19
1971	727.60	72.55	818.60	81.62
1972	758.40	71.82	865.50	81.96
1973	790.40	71.30	911.50	82.23
1974	828.50	70.83	965.70	82.56
1975	864.30	70.65	1014.30	82.91
1976	873.50	69.68	1036.40	82.68
1977	885.20	69.18	1055.20	82.46
1978	906.20	68.96	1082.70	82.40
1979	919.90	68.62	1101.80	82.19
1980	939.40	68.40	1128.10	82.15
1981	962.80	68.23	1158.60	82.10
1982	969.00	67.68	1170.20	81.74
1983	963.60	66.92	1169.70	81.23
1984	971.70	66.38	1188.70	81.21
1985	983.50	65.95	1211.30	81.22

Source: Appendix C.

Share of science workers without degree fell from 2/3 to

about 60% from 1950-1956, then grew to 78% in 1965, and has been declining ever since. Now it has almost reached the 1950 level: 67%. Sharp increase in this share in 1962 was due the inclusion of science workers at the enterprises, with low share of workers with degrees. The share of workers without scientific rank was increasing monotonically till 1975, rising from 62 to 83%. After that it has marginally declined. The latter share peaked later, and declined by less than the former. Explanations for that are the increasing share of people with degrees in industry, where they do not get scientific ranks, and loss of significance by some ranks, such as MNS.

The share of doctors and candidates in higher learning institutions is much higher than in other systems of R&D.[10]

A.4 Expenditures: definitions and scope.

Soviet statistics reports expenditures "on science" out of the state budget and out of all sources. "All sources" include the state (Union, republic, and local) budget; expenditures of state and cooperative enterprises and organizations out of own funds, and out of budget funds allocated to them for general economic purposes; and expenditures from other sources.[11] These other sources can only be bank credit.

"Science" means "science and science services", as defined

---

[10]Sominskii, Torf, 1972, p. 42.

[11]NKh-74, 831.

in A.1.[12] Expenditures on any non-institutionalized R&D, as well as the expenditures of R&D units of enterprises of other sectors of the economy are not included.[13] Expenditures on all the activities that really should not be classified as R&D, such as geological and fisheries surveys, and hydrometeorological service, are included.

Kvasha (1973, p. 222), who had unparallelled understanding of Soviet statistics, stated that investment into and current cost of production of space research equipment is not included in the data. This must mean that production of all space equipment is concentrated in other sectors, and accounted for there; equipment is then provided for the scientific uses free of charge.

Funding of research done in higher learning institutions is included in science expenditures only partially.[14] Work done according to individual and departamental research plans and financed through education budget (out of which regular salaries of teaching personnel are paid) is not included. Only the work done according to the state plans and financed from the budget R&D allocations, and contract work are counted. It is estimated

[12]See, e. g., Kvasha, 1973, p. 222; Grinchel', 1974, pp. 8-10.

[13]"Data on the scale and nature of R&D on many enterprises do not exist. Collection and aggregation of this information is not prescribed by any statistical reporting procedure, and can be obtained only as a result of special study." Kanygin, et al., 1972, p. 45.

[14]Grinchel', 1974, pp. 38-9. Kvasha (1973, p. 222), surprisingly, states that it is not included at all.

that one third of the salary of teaching personnel actually covers time spent on R&D time, adding about 2% to the total R&D expenditures.[15]

According to the statistical yearbook, science expenditures from all sources include investment.[16] R&D expenditures from the state budget exclude investment.[17] Investment in construction of sectoral R&D institutions is planned and accounted for within the investment totals of respective sectors.[18] Hence, investment in sectoral R&D is not included in science expenditures data.

What is meant by investment here is the outlay on construction of new facilities and on their initial equipment. It is accounted for in item # 15 - "investment according to the state plan" - in the financial statement (smeta) of R&D organization.[19] Equipment purchases for the on-going institutions are financed out of the funds allocated for a particular project and are counted as current expenditures, not as investment.[20] They are reflected item (statia) #12 (purchase of scientific instruments and equipment), and "fund for expanding material-technical base".[21] Depreciation is not included in R&D expenditures, this

---

[15] ibid.

[16] NKh-74, 831.

[17] Grinchel', 1974, pp. 8-10.

[18] Gosplan, 1974, p. 785.

[19] Bogaev, et al., 1972, p. 5.

[20] Nedil'ko, 1985, p. 66.

[21] Nedil'ko, 1985, pp. 86-7.

being a non-productive sector. Replacement of capital assets occurs from budget allocations for capital repair and new equipment purchases.[22]

Item 1 in the budget of R&D organizations includes all kinds of salary paid to full-time (shtatnye) employees. Item 2 - other labor-related expenditures (nachisleniia na zarabotnuiu platu).[23] Item #5 - R&D, or purchases of materials, mock-ups, services of experimental and pilot production units.[24]

A.5 Sources of financing.

Changes in the sources of financing of R&D are the result of two conscious policies: making sectors pay for some of the cost of their R&D, and increasing the participation of Academies in innovation process.

Change in financing of sectoral R&D was decreed in 1961.[25] The share of the enterprises in total financing increased, as a result. 1967 and 1968 decress provided further push in the same direction (see Table A-5).

There are two aspects in analysis of sources of financing: who originally provides the funds, and who disburses them. In the 1960s and 1950s, the share of budget outlays is well above 50%, though the data are not sufficient to detect a trend.

---

[22] Zavlin and Iudelevich, 1985, p. 66.

[23] Bogaev, et al., 1972, p. 4.

[24] Nedil'ko, 1985, pp. 86-7.

[25] See 3.6 above.

Table A-5. Share of budget outlays in total science expenditures, %%.

Year	(1)	(2)	(3)	(4)
1950	58.22	60.00	50.50	53.90
1951				
1952				
1953		55.75		
1954				
1955				
1956		59.54		
1957				
1958		70.08		
1959		60.73		
1960	59.33	55.69	55.69	59.97
1961				59.47
1962				
1963				59.72
1964	61.72			62.05
1965	61.81	59.80		
1966	61.49		59.89	
1967	61.59		60.13	
1968	61.37			
1969	58.84			
1970		54.91		
1971		53.20		
1972		50.70		
1973		47.78		
1974		47.87		
1975		45.36		
1976		44.62		
1977		44.75		
1978		45.48		
1979		45.94		
1980		44.60		
1981		45.77		
1982		46.40		
1983		47.50		
1984		46.82		
1985		47.01		

Source: Appendix C.

There are basically two sources both for funds origination and for disbursement: the budget allocations and the funds of enterprises and ministries. But the disbursement of budget allocations may occur directly or through the enterprises and

ministries.

Table A-6. Structure of financing of sectoral R&D, shares, %%.

Source	1964	1968	1971	1980
State budget			31.0	7.2
Own funds of sectors			69.0	92.8
including:				
payments out of cost			18.9	9.9
contract proceeds	29.0	40.1	39.7	35.7
EFRNT			10.4	47.2

Note: the shares of contract financing for the 1960s may relate to all R&D, rather than sectoral. Sources: Anisimov, et al., 1969, p. 135; Iampol'skii, 1984, p. 209, based on Finansy SSSR, no. 10, 1981, p. 35.

Table A-7. Structure of financing in sectoral science establishments, shares, %.

Sector	1976			1981		
	centralized	contract	other	centralized	contract	other
Industry	51.5	42.1	6.4	36.0	61.6	2.4
Agriculture, forestry, water	69.2	29.1	1.7	64.3	30.8	4.9
Construction	44.2	55.8	-	53.9	44.0	2.1
Health	94.6	5.4	-	76.6	23.3	-
Economics	77.5	22.5	-	75.7	23.6	0.7
Other	29.1	70.9	-	24.5	75.5	-
Total	54.9	40.7	4.4	44.2	53.5	2.3

Source: survey of 49 institutions in Minsk in Nedil'ko, 1985, p. 73.

A.6 Allocation of resources by stage of R&D.

Allocation of resources among the stages of R&D process (basic and applied research, development and testing) used to arouse passions among Soviet scholars in the late 1960s-early 1970s. It was argued that the development stage is getting too

few resources to be able to develop the results of the research stage. The argument was bolstered by comparing the Soviet estimates of expenditures shares with those in the West.[26] Soviet distribution of expenditures was top-heavy, according to these estimates, with larger share going to research, and Western distribution favored development. The estimates (columns (a) in Table A-8) were quoted widely.[27] Another set of estimates, whith Soviet shares similar to those in the West, put the argument to rest (column (b), Table A-8).

Table A-8. Expenditures by stage of R&D, shares, %.

	1967	1968	1970		1971 (plan)	1971-80
	(a)	(a)	(b)	(c)	(d)	(e)
Fundamental research	12.7	12.9	14	29	27	9
Applied research	60.0	60.5	22	40	55.6	28
Development	26.9	27.3	64	31	17.5	63

(a): excluding investment; Grishaev, 1970, p. 19, as quoted in Bashin, 1974, p.98. (b), (c): Gvishiani, 1973, p. 143; (c) excludes expenditures of most heavy industry ministries.
(d): Kanygin, 1974, p. 227. (e): Pokrovskii, 1983, p. 49.

There is no statistical reporting on this aspect of R&D, so that

---

[26]See, e. g., Gatovskii, 1971, pp. 130, 145.

[27]Gatovskii, 1971, p. 130, 145; <u>Materialy Vsesoiuznoi nauchnoi konferentsii po ekonomicheskim problemam nauchno-tekhnicheskogo progressa.</u> issue 2. Moscow: 1970, p. 237, as quoted in Bashin, 1974, p.97; Kosov, Ie. V., "Intensivnyi put' razvitiia i problemy upravleniia", in: <u>2-ia Vsesoyuznaia nauchno-tekhnicheskaia konferentsiia. Problemy nauchnoi organizatsii upravleniia sotsialisticheskoi promyshlennostiu.</u> no. 6, Tezisy dokladov. Sektsiia no. 5. Moscow: 1972, p. 58, as quoted in Iampol'skii and Galuza, 1976, p. 91.

all the data are estimates of individual experts.[28] This story brings out the ambiguity of the concept of R&D stages. These do not neatly follow each other, but are interwined in the development of any one product, or in the work of people and institutions.

Table A-9. Detailed characterization of R&D stages in 1971.

Stage	Number of projects shares, %	Number of establishments, shares, %	Planned project duration, years	Planned outlays, shares, %	Average estimated outlay per project, thousand rubles
Basic research	19.8	27.5	3.88	24.6	108.67
Applied research	57.6	34.6	2.72	50.8	23.76
Testing & design	8.8	15.4	2.79	16.0	83.52
Implementation	7.4	14.7	2.55	6.9	46.42
Other	6.4	7.8	3.74	1.7	32.01
Total	100.0	100.0	3.01	100.0	61.64

Source: Kanygin, 1974, p. 227.

Surveys of scientists in Union academy found that only 31% of them engage exclusively in fundamental research; the majority also engages in applied research and, to a lesser degree, in development. The same was found for the scientists in higher learning institutions.[29] Therefore, any aggregate estimates of resources devoted to each stage would crucially depend on some strong assumptions, and estimates based on different assumptions will not be comparable. As can be seen from Table A-9, such

[28]Zavlin et al., 1973, p. 4.

[29]Kuge' and Shelishch, 1979, p. 34.

assumptions should be made about the classification of projects and institutions by stage, a dubious exercise on the macro level

Table A-10. Employment in basic research (science workers?), thousands.

1960	1965	1968	1973
62.0	76.6	96.7	112.0

Bashin, 1974, p. 107, quoting V. G. Lebedev and G. G. Plekhov, Rol' nauki v razvitii proizvodstva. Moscow: 1971.

One guess as to the origin of the estimates in Table A-8 ties them to the real processes of allocation, analyzed in two subsequent sections. The expansion of R&D in the late 1950s and 1960s occurred mostly on account of research institutions. Employment in such institutions came to dominate R&D employment. It is plausible that the estimates of low share of development in R&D expenditures identified those as expenditures in organizations formally designated as "design" establishments. At the same time as the number and size of research institutions was growing out of proportion with design ones, their functions were changing. Already in the 1970s, much of what sectoral NII were doing was not research. Part of it must have been design. So the estimates in Table A-8 which give more weight to design, probably take into account that organizations labeled "research" do a great lot of design.

In the early 1970s, it was estimated that if the average share of fundamental research in total expenditures is 14-15%, in sectoral institutes it is 5-10%, while in academic institutes, it

reaches 60-70%. At the enterprises, 70-80% of expenditures on R&D goes towards the improvement of existing products, and only 20-30% - towards the creation of new products.[30]

Shchelishch (1981, pp. 116-8) conducted a survey of science workers in some institutes of the academy, sectoral NII, and teaching institutions, investigating time spent on different stages of R&D.

Table A-11. Time spent by researchers by stage of R&D.

Stage of R&D	Academy	Sectoral NII	Teaching(*) institutions
Basic	57	10	21
Applied	30	41	45
Development	8	40	16
Implementation	5	9	18

* - Non-research functions excluded.

The shares of time spent by science workers in the sample institutions were then extrapolated to all science workers in a pacticular class of institution. The results are in Table A-12.

Table A-12. Breakdown of time spent on different stages of R&D, in % shares of total number of science workers.

Stage of R&D	Academy	Sectoral NII	VUZy	Total
Basic	5.0	4.5	3.0	12.5
Applied	2.6	20.0	6.5	29.1
Development	0.6	19.0	2.3	21.9
Implementation	0.4	4.0	2.7	7.1
Total	8.6	47.5	14.5	70.6

Excluded are science workers outside of R&D establishments (8%) and the equivalent of 22% of science workers employed by teaching institutions and not doing research.

[30] Grinchel', 1974, p. 12.

A.7 Time lags between inputs and outputs.

"The period from the start of applied research to the introduction of its results into production is now about 5-6 years."

According to the data of fourteen leading research institutes in machinebuilding, the average period from the start of research to series production is 5.1 years; 8-10 years appears to be the longest period.

Average period of development for agricultural machinery in 1970 was 5 years, and for tractors - 6-7 years.

Budavey, Panova (1974, p. 21) refer to an unnamed study that found 6-9 years to be the duration of "research-production cycle" in machinebuilding and instruments industry.

"Five-six years elapse from the formulation of a scientific topic to the decision to produce new type of equipment."

Calculations for 1789 samples of new technology in the Soviet industry have shown the average period of design (sozdanie) to be 2.2 years.

It is instructive to contrast these data with gestation periods for innovations in the US firms. Pakes and Schankerman (1984, pp.82-4) summarized relevant data from Rapoport (1971) and Wagner (1968). The total period of applied research, development and manufacturing and marketing start-up is estimated as 1.17-2.62 years for different sectors. This number, incredibly low compared to the Soviet data assembled above, is believed to be upward biased!

Table A-13. Time lags between R&D expenditures and results in machinebuilding, years.

	Reports, drawings, descriptions	Journal publications	Patents
Research	2-4	3-5	3-6
Development	1-3	2-4	3-5

Source: Grinchel', 1974, p. 22, based on a survey.

The duration of a research project at an R&D organization varies from 1 year for contract work to 5-7 years for large projects that end in designing a new machine and testing its models. According to VNTITsentr, average planned duration of applied research projects that started in 1970 was 3 years, with 16% of projects taking less than 1 year, 31% - 1-2 years, 20% - 2-3 years, and one third of the projects - over 3 years.

Table A-14. Duration of R&D projects by sector in 1969-1970, years.

	Applied research	Development	Total
Electrotechnical	3.1	3.4	6.5
Machine tools	2.0	3.7	5.7
Instruments	2.2	2.1	4.3

Source: Grinchel', 1974, p. 58.

Creation and mastering (osvoenie) of new technologies that have analogues takes 3-5 years; radically new technology takes twice as long.

A.8 Prototypes of new equipment.

The title of the table with prototype data in statistical yearbooks has initially been "the number of the most important new types of machines and equipment created" (thus suggesting

selective coverage) and "number of new kinds (vidov) of instruments created". In the mid-1960s, the title was changed to "the number of models of new types of machines and equipment and instruments created" (suggesting full coverage). The contents of the tables show that both titles refer to the same set of numbers.

Data on prototypes are collected according to the form "Information on prototypes of new machines, equipment, apparatus, and instruments created for the first time in the USSR (one-time [iedinovremennaia])". For each prototype, along with its brief technical characteristic, and technical and economic advantages, the form records the year when development started, whether the prototype was recommended for production (and if not, why), and projected date of production of first industrial series.[31]

It is not clear what kinds of units are covered by the survey. It must cover specialized machinebuilding ministries. Specialized machinebuilding NII and KB of non-machinebuilding ministries (e. g., designers coal-mining equipment subordinate to the Ministry of coal-mining) also may be covered. I doubt that machines designed within non-machinebuilding plants for own use (e. g., shoe-making machinery designed at a shoe making factory) is covered by the survey.

Marin and Pavelko, 1974, p. 35; Bliakhman, 1979, p. 228; and Tsigel'nik, 1971, p. 115, all imply that the data relate to prototypes created. Grinchel', 1974, p. 63 states that they

[31]Tsigel'nik, 1971, p. 115; Marin and Pavelko, 1974, p. 35.

relate only to the accepted prototypes, but this is contradicted by a mass of other evidence.

When a unique machine or piece of equipment is being developed, no prototype physically separate from the machine itself is created. Do the data on prototypes created include the number of unique machines created? One source suggests that data on the number of prototypes created do count unique machines, while data on the number of new machines put into production count only teh models produced in series.[32] However, elsewhere the same author states that data on new products put into industrial production include unique goods.[33] The data on new machines put into production are published under the title "The number of types of industrial products put into production for the first time in the USSR".[34] But before that, some of the same numbers appeared in the footnotes to the tables with the number of prototypes created, and were characterized as "the number of models put into series production".[35]

It appears that unique products are included in the data on both creation and implementation of new models of machines; term "series production" being in this case synonimous with "production."

---

[32]Tsigel'nik, 1971, p. 114.

[33]ibid., p. 117.

[34]NKh-83, p. 101.

[35]E. g., NKh-79, 113.

A.9 Researchers and support personnel in the Academies of Science.

In the 1970s, ratio of researchers to support personnel in the Ukrainian Academy remained stable, while the share of personnel in development organizations working on contract basis increased significantly (Table A-15).[36]

Table A-15. Employment in Ukrainian academy of sciences, shares and growth rates, %%, on Jan. 1.

	shares 1971	share 1976	share 1981	growth rates 1976/71	1981/76
R&D organizations	67.7	57.9	49.6	29.1	11.2
researchers	24.9	24.1	18.2	21.5	17.9
support personnel	42.8	37.8	31.4	33.5	7.7
Experimental, testing, and other organizations	32.3	42.1	50.4	97.1	55.6
Total				51.4	30.0

Source: Marushchak and Iakovlev, 1984, p. 9.

Table A-16. Structure of personnel of Bielorussian Academy of Sciences, shares, %%.

Division of Academy	1965			1971		
	researchers	auxiliary	other	researchers	auxiliary	other
Physics & mathemat.	69.6	16.4	14.0	51.2	36.3	12.5
Physics & technical	74.1	14.8	11.1	50.8	41.5	7.7
Chemical & geology	66.4	23.4	10.2	60.5	32.1	7.4
Biological	54.0	28.9	17.1	52.9	36.1	11.0
Social	78.7	14.4	6.9	54.4	21.7	5.9
Total	69.2	18.5	12.3	54.4	36.4	9.2

Source: Dronov, 1974, p. 126.

Data for Bielorussian Academy are contradicory: while Table A-16 indicates doubling of the share of support personnel in the

[36] Marushchak and Iakovlev, 1984, p. 10.

late 1960s, another source states that this share was falling since 1966, though increased from 39.2% to 52.5% in 1961-5.[37]

In 1970, science workers represented 36.2% of the total Union Academy employment, varying from 26.3% in physical, technical, and mathematical sciences section to 63% in social sciences section.[38]

---

[37]Nedil'ko, 1985, p. 83.

[38]N. I. Kochetova, "Nauchnye kadry v perspektivnykh planakh nauchnykh uchrezhdenii", in Nauka i tekhnika, issue VIII, part I, Leningrad, 1973, p. 81, quoting Nauchno-tekhnicheskaia revoliutsiia i izmenenie struktury nauchnykh kadrov, M., 1973, p. 32.

APPENDIX B. Rejected hypothesis: shifts in regional structure of R&D as a cause of the productivity decline.

Soviet Union is an ethnically heterogenous country. Its constituent parts have different cultures and levels of development. It is to be expected that these would result in varying productivity of R&D in different parts of the country. If the share of R&D resources going to less productive regions has been increasing over time, this must have brought down the average national R&D productivity.

B.1 Regional differences in R&D productivity.

B.1.1 Why R&D productivity differs by region.

In the early years of Soviet power, science was heavily concentrated in Moscow, Leningrad, and, to a much lesser degree, in a few other cities with universities. This is were scientific tradition was located. Republican academies and higher learning institutions in the periphery were being created as a political gesture to the non-Russian population, and as a means of pulling the less developed regions up to the level of more developed. Sectoral R&D establishements followed industrial development.

Many of the regions to which science was being spread were lacking not only modern scientific tradition, but also qualified personnel (local population being largely illiterate).[1] Scienti-

[1] Iefimovskaia, 1972; Duzhenkov, 1972, p. 102 speaks of lack of people with higher education.

fic institutions that were created by decrees from the center had to be staffed with underqualified personnel. Low quality of researchers is perpetuated through recruitment procedures fraught with bribery and nepotism, and through generally low standards.[2] Union Academy, and leading universities, and other R&D organizations in large Russian cities in many cases attract the most able non-Russians.

Today, extra-scientific considerations still figure prominently in organization of republican academies. Thus, it is alleged that out of considerations of national prestige, they copy the structure and directions of research of the Union Academy, without any regard for availability of qualified researchers or equipment.[3]

B.1.2 Data on productivity differences.

Data allow us to deal only with fifteen Union republics. One of these, Russian republic, is itself very large and quite heterogenous, but we are unable to delve into R&D productivity differentials within it.

There is both qualitative and quantitative evidence of productivity differentials. Observers note generally lower quality of R&D establishments in non-Russian republics, especial-

---

[2]See Vyzhutovich, 1986, on corruption in Kirgiz Academy; Tarasov, 1986, on Uzbek Academy; Iesil'baev and Petrushov, 1986, on Kazakh Academy.

[3]Tursunov, 1986.

ly in Central Asia, and Trans-Caucasian republics.[4] Not all non-Russian republics have weaker Academies than Russia. Ukrainian Academy is on a par with the Russian one.[5]

The volume of R&D performed per science worker in republican academies is two to three times lower than in Union academy.[6] But this, of course, reflects a number of different influences, such as the disciplinary structure and availability of funds, support personnel, and equipment.

Three measures of inventive productivity by republic are given in Table B-1: patent applications per thousand of science workers; patents granted per thousand of science workers, and rate of approval of applications. For the first two measures, we calculate relative productivity: productivity in each republic as a percentage of the highest republican productivity. Names of republics are arranged in the order of decreasing productivity in terms of patents granted, the most important measure in the table. The table shows great variation of this meausre by republic, with tenfold differential between the most and the least productive. Difference in applications is somewhat smaller. This means that the republics which are the least productive of patents, also submit patent applications of lower

---

[4]Popovsky (1979), former Soviet writer on science, devotes a whole chapter (Chapter 6) of his account of the modern Soviet science to this subject. See also Kresin (no date, p. 22), who was a physicist at the Union Academy of Sciences.

[5]Kresin, p. 22

[6]Chemodanov, 1978a, p. 126.

quality.

Table B-1. Inventive productivity of science workers by republic in 1976.

	Applica- tions per thousand	Relative producti- vity, %	Patents granted per thous	Relative producti- vity	Approval rate, %
Ukraine	126.7	100.00	54.7	100.00	43.22
Latvia	107.5	84.85	52.9	96.71	49.22
Bielorus	120.5	95.11	49.3	90.13	40.89
Lithuania	102.2	80.66	48.9	89.40	47.92
Russia	84.6	66.77	38.9	71.12	46.03
Moldavia	93.6	73.88	35.4	64.72	37.92
Estonia	50.7	40.02	23.7	43.33	46.02
Kazakh	55.8	44.04	22.4	40.95	40.20
Georgia	42.1	33.23	18.3	33.46	43.36
Uzbek	38.8	30.62	14.7	26.87	38.08
Armenia	31.2	24.63	14.1	25.78	45.36
Tadjik	25.8	20.36	13.6	24.86	27.84
Azerbaid	33.4	26.36	12.9	23.58	38.55
Kirgizia	35.4	27.94	10.0	18.28	28.19
Turkmenia	22.6	17.84	5.4	9.87	24.04

Source: Artem'ev and Kravchenko, 1979, p. 51.

A twofold differential in the rate approval of applciations between the more and the less productive republics supports that conclusion. It should also be noted that the approval ratio, a proxy for quality of applications, varies by republic less than productivity.

Table B-1 clearly shows a split between the more productive Slavic and Baltic republics, plus Moldavia (Europe) and less productive Trans-Caucasian and Central Asian republics and Kazakhstan (Asia). This broadly coincides with the evidence presented above. There are a few things that I would not have predicted: Bielorussia and Lithuania ranking higher than Russia, and Moldavia - higher than Estonia. Notice, however, comparatively low approval rates in Bielorussia and Moldavia.

8.2 The structure of republican R&D.

While part of the difference in productivity measures of republics presented above is due to the regional (cultural and historical) conditions, another part is due to the differences in sectoral and disciplinary structures of republican R&D. Propensity to patent differs markedly across scientific disciplines (see 14.2). It is also likely to differ for the same discipline in different systems of R&D (academy, sectoral science, and higher learning). Differences in productivity among republics reflect different shares of academies and higher learning institutions in their R&D reosurces, as well as varying allocations by discipline.

Causality does not run in only one direction here. We would argue that the purely regional (cultural and historical) differences in productivity influenced which types of R&D institutions and scientific disciplines got developed in particular republics. The share of science workers in academy and higher learning institutions in the total number of science workers in a given republic may serve as an indicator of the strength of republican science. The higher this share, the weaker is the R&D establishment. Low share of sectoral R&D signifies weak industrial base, which correlates with the general low level of development; the share of academies and higher learning insitutions, created for political reasons, will be high, and the

overall quality of R&D establishment - low.[7]

Indeed, the share of science workers in the academy is low (5%) for Russian republic, and only slightly higher in Ukraine (7%) (see Table B-2).

Table B-2. Science workers in academies as a share of all science workers by republic, %%.

Year	Russia	Ukraine	Bielo-russia	Uzbek	Kazakh	Georgia
1959	10.88	8.21	20.69	20.16	17.91	26.35
1961	6.86	8.77	23.48	25.95	16.32	26.13
1963	5.68	7.39	12.85	15.78	12.12	20.63
1964	5.62	7.06	12.21	16.09	11.90	20.38
1965	5.63	7.47	13.31	15.90	13.21	21.51
1966	5.55	7.96	14.45	15.54	12.72	23.15
1967	5.67	7.76	14.92	14.06	12.37	22.09
1968	5.75	7.99	15.12	13.97	12.25	22.06
1969	5.71	8.00	14.87	13.60	11.85	21.88
1970	5.56	7.82	14.22	12.92	11.57	20.58
1971	5.34	7.79	15.84	12.71	11.41	20.84
1972	5.30	7.76	15.31	12.87	11.59	20.28
1973	5.08	7.54	17.75	12.74	11.61	20.76
1974	5.01	7.17	15.04	12.12	11.75	21.28
1975	4.99	7.06	14.97	11.97	11.66	21.97
1976	4.97	7.05	14.27	11.33	11.32	22.04
1977	5.03	6.77	14.18	11.26	10.65	21.65
1978	5.07	6.72	14.53	11.26	10.74	21.87
1979	5.02	6.75	14.30	11.13	11.05	20.65
1980	5.10	6.83	14.12	10.99	11.07	22.29
1981	5.09	6.83	13.98	11.39	10.98	21.68
1982	5.08	6.76	14.00	10.79	10.63	21.73
1983	5.15	7.04	14.04	10.71	10.67	21.09
1984	5.20	7.16	13.90	10.74	10.83	20.87

Source: NKh.

[7]Agursky (1976, p. 7) states that military production plants are concentrated almost exclusively in Slavic republics; this should be also true for military R&D organizations.

At the same time, it is around 20% in Georgia, Azerbaidjan, and Turkmenia, and around 15% in Armenia, Tadjikistan, Kirgizia, Estonia, and Bielorussia. Kazakhstan and Uzbekistan have the lowest share of science workers in academy among all the peripheral republics (11%), but it is still much higher than that of Russia and Ukraine.

Table 3-2. Continued.

Year	Azer-baid.	Lithu-ania	Moldavia	Latvia	Kirgizia	Tadji-kistan	Armenia
1959	25.37	17.97	15.71	26.33	26.42	34.07	25.64
1961	26.05	17.38	14.92	27.62	27.42	24.64	24.62
1963	22.28	11.66	14.14	18.57	20.64	20.55	19.93
1964	21.43	11.31	13.63	18.90	21.63	20.79	19.17
1965	20.79	11.95	13.76	19.38	22.46	20.09	19.76
1966	20.24	12.40	13.28	17.62	22.69	21.83	19.00
1967	20.97	11.89	13.01	16.09	21.15	20.88	17.88
1968	22.09	12.27	12.90	16.82	20.16	20.43	17.54
1969	21.41	12.53	13.19	16.52	20.00	20.38	19.40
1970	19.50	12.70	12.07	16.57	19.27	18.94	17.21
1971	20.28	13.25	12.02	16.93	19.56	18.33	16.45
1972	19.55	13.84	12.05	17.33	19.48	18.05	17.18
1973	20.64	13.16	12.70	16.10	19.07	18.39	16.98
1974	20.32	12.66	12.28	15.27	20.07	19.03	16.96
1975	19.82	12.27	12.10	14.67	20.20	18.38	16.58
1976	19.82	12.24	12.26	14.94	20.00	18.56	16.47
1977	19.71	12.30	11.97	14.92	19.16	18.36	17.47
1978	19.86	12.25	11.80	14.66	18.72	17.63	16.82
1979	20.02	12.08	11.59	13.71	18.52	17.33	16.17
1980	19.61	12.08	12.03	13.75	18.40	17.42	15.66
1981	19.78	12.14	12.32	13.50	17.90	17.13	15.94
1982	19.87	12.38	11.88	12.80	17.85	16.55	14.92
1983	19.97	12.49	11.97	12.11	16.77	16.59	15.05
1984	20.10	12.71	11.69	11.93	16.87	17.96	15.04

There is a gap between Russian and Ukrainian republics, on one hand, and the rest, on the other. According to some es-

timates, the share of science workers in higher learning institutions varies across republics parallel to that of science workers in academy.[8]

Table B-2. Continued.

Year	Turkmenia	Estonia
1959	28.04	23.73
1961	29.55	26.88
1963	22.95	17.72
1964	22.19	16.79
1965	24.15	17.14
1966	22.12	17.22
1967	20.28	16.96
1968	19.85	16.40
1969	18.66	15.98
1970	19.11	16.38
1971	19.13	16.22
1972	18.43	15.75
1973	18.51	16.17
1974	17.76	15.95
1975	18.83	15.82
1976	19.20	17.00
1977	20.63	16.62
1978	18.46	16.42
1979	19.35	16.57
1980	19.44	17.23
1981	19.88	16.36
1982	19.75	16.34
1983	19.68	15.54
1984	19.25	16.28

Data on the fields in which science workers in different republics worked in 1972 (Tables B-3 and B-4) are consistent with this general characterization of republican R&D establishments.

[8] Kassel and Campbell, 1980, p. 42.

The share of science workers in technical disciplines in the total in Russian and Ukrainian republics is higher than their share in Union total. Russia and Ukraine together account for 90% of all science workers in technical sciences. And technical science is what sectoral R&D is all about. On account of this, sciences in Russia employ larger share of science workers, than in the Union, and social sciences and humanities - smaller. Agricultural, medical, and biological sciences are split between Russia and the rest of the country equally.

Table 8-3. Distribution of science workers in scientific disciplines by republic, end of 1972, shares %%.

	USSR	Russia	Rest of the country	Ukraine
Total	100	68.56	31.44	13.76
Physics & mathematics	100	66.77	33.23	14.71
Chemistry	100	67.61	32.39	12.61
Biology	100	58.77	41.23	12.31
Geology & mineralogy	100	68.13	31.87	8.97
Technical	100	75.56	24.44	14.03
Agricultural & veterinarian	100	50.80	49.20	14.21
Medical & pharmaceutic	100	56.92	43.08	16.35
Total sciences	100	70.32	29.68	13.97
Social sciences, humanities, & misc.	100	63.09	36.91	13.11

Source: NKh.

The structure of republican R&D by discipline is also reflected in the structure of their expenditures. In the academies of Central Asian and Transcaucasian republics, Lithuania and Moldavia, the share of wages in expenditures remained above 50% in the late 1960s, when the average share for all

academies dipped below this figure.[9]

Table B-4. Distribution of science workers in republics by scientific discipline, end of 1972, shares, %%.

	USSR	Russia	The rest of the country	Ukraine
Total	100.00	100.00	100.00	100.00
Physics & mathematics	10.05	9.79	10.62	10.75
Chemistry	4.72	4.65	4.86	4.32
Biology	3.96	3.40	5.20	3.54
Geology & mineralogy	2.12	2.11	2.15	1.38
Technical	45.92	50.61	35.71	46.82
Agriculture & veterinary	3.66	2.72	5.74	3.78
Medical & pharmac.	5.22	4.33	7.15	6.20
Total sciences	75.66	77.60	71.43	76.80
Social sciences, humanities, & misc.	24.34	22.40	28.57	23.20

Source: NKh.

These structural differences conform well to the regional productivity differentials discussed in B.1.

B.3 Trends in allocation of resources among republics.

Differences in R&D productivity among the regions do not appear to have influenced the general productivity trend, because the shares of the regions with different productivity in the total R&D effort remained approximately stable. At least as far as the aggregate data are involved, the share of republics with weaker R&D sector in the total effort has not been increasing. Indeed, the share of Russian republic in R&D employment fell from 74.4% in 1957 to 70.3% in 1974, but this was more than compen-

[9] Duzhenkov, 1972, pp. 101-2.

sated by an increase in the share of Ukraine, from 8.9% to 13.6% (see Table B-5). The share of Kazakhstan and Central Asian republics declined, and the share of the republics on the western border of the Union (except Estonia) and of Armenia increases.

Table B-5. Distribution of R&D employment by republic, shares, %%.

Year	Russia	Ukraine	Bielorussia	Uzbek	Kazakh	Georgia	Azerbaidz.
1957	74.42	8.94	1.16	2.15	5.46	1.49	1.24
1958	73.84	9.27	1.12	2.24	5.38	1.57	1.27
1961	72.03	10.46	1.78	2.49	4.47	1.37	1.32
1963	71.43	12.49	1.56	1.98	4.18	1.31	1.35
1967	71.30	12.95	1.61	2.00	3.89	1.40	1.12
1969	71.10	12.92	1.82	1.98	3.80	1.47	1.15
1972	70.60	13.40	2.09	1.83	3.53	1.47	1.13
1974	70.34	13.64	2.23	1.92	3.39	1.48	1.11

Source: NKh.

Table B-5. Continued.

Year	Lithuania	Moldavia	Latvia	Kirgizia	Tadjikistan	Armenia	Turkmenia	Estonia
1957	0.50	0.33	0.66	1.08	0.83	0.75	0.66	0.33
1958	0.52	0.37	0.60	1.12	0.82	0.82	0.67	0.37
1961	0.71	0.76	0.66	1.22	0.66	0.96	0.61	0.51
1963	0.80	0.55	0.72	1.10	0.59	0.97	0.51	0.46
1967	0.88	0.67	0.84	0.91	0.56	0.88	0.49	0.49
1969	0.86	0.64	0.77	0.93	0.54	1.02	0.48	0.51
1972	0.96	0.68	0.82	0.87	0.62	1.07	0.42	0.51
1974	0.98	0.54	0.83	0.93	0.62	1.06	0.39	0.54

Russian share of science workers does not change at all over 1950-83; the shares of Ukraine, Bielorussia, Lithuania, Moldavia, and Armenia were increasing, while those of Georgia, Azerbaidjan, Latvia, Turkmenia, and Estonia decline (Table B-6).

Table 8-6. Distribution of science workers by republic, shares, %

Year	Russia	Ukraine	Bielo-russia	Uzbek	Kazakh	Georgia	Azer-biadz.
1950	68.74	13.78	1.60	2.77	2.03	3.02	2.09
1953	68.54	13.72	1.73	2.73	2.11	2.74	2.03
1955	69.14	13.50	1.84	2.65	2.15	2.53	1.96
1956	69.28	13.26	1.85	2.68	2.24	2.45	1.94
1957	68.95	13.04	1.94	2.81	2.37	2.59	1.95
1958	68.60	12.87	1.95	2.92	2.76	2.64	1.98
1959	68.62	12.87	1.95	2.94	2.70	2.55	2.05
1960	68.59	13.19	1.92	2.91	2.71	2.60	2.03
1961	68.79	13.22	1.89	2.90	2.75	2.52	1.92
1962	69.12	13.54	1.98	2.77	2.66	2.32	1.89
1963	68.79	13.93	2.03	2.65	2.78	2.29	1.87
1964	68.55	14.21	2.15	2.52	2.82	2.21	1.86
1965	68.84	14.14	2.21	2.45	2.74	2.14	1.87
1966	68.59	13.89	2.26	2.51	2.87	2.10	1.97
1967	68.63	13.92	2.22	2.59	2.87	2.06	1.89
1968	68.52	13.87	2.26	2.71	2.81	2.06	1.91
1969	68.29	13.90	2.34	2.73	2.87	2.11	1.88
1970	68.03	13.98	2.36	2.72	2.89	2.18	1.84
1971	68.63	13.71	2.40	2.62	2.77	2.12	1.81
1972	68.56	13.76	2.48	2.59	2.74	2.12	1.81
1973	68.62	13.89	2.45	2.54	2.70	2.10	1.78
1974	68.77	13.86	2.50	2.51	2.61	2.06	1.76
1975	68.54	14.02	2.53	2.53	2.62	2.04	1.74
1976	68.88	13.86	2.65	2.50	2.63	1.94	1.71
1977	68.64	14.03	2.70	2.52	2.63	1.95	1.70
1978	68.61	14.09	2.67	2.56	2.64	1.94	1.63
1979	68.48	14.16	2.72	2.56	2.69	1.86	1.62
1980	68.28	14.26	2.77	2.57	2.72	1.83	1.60
1981	68.27	14.21	2.79	2.59	2.73	1.84	1.60
1982	68.15	14.35	2.72	2.56	2.73	1.85	1.59
1983	68.37	14.12	2.72	2.59	2.75	1.85	1.60
1984	69.64	14.23	2.79	2.63	2.76	1.85	1.62

Source: NKh.

Table B-6. Continued.

Year	Lithuania	Moldavia	Latvia	Kirgizia	Tadjikistan	Armenia	Turkmenia	Estonia
1950	0.86	0.43	1.35	0.49	0.43	1.23	0.43	0.74
1953	0.96	0.53	1.33	0.63	0.48	1.19	0.50	0.75
1955	0.92	0.55	1.16	0.64	0.57	1.12	0.53	0.72
1956	0.92	0.57	1.16	0.70	0.60	1.09	0.53	0.73
1957	0.90	0.59	1.13	0.68	0.61	1.14	0.55	0.73
1958	0.90	0.57	1.08	0.69	0.63	1.18	0.54	0.70
1959	0.90	0.56	1.00	0.66	0.67	1.32	0.54	0.68
1960	0.93	0.56	0.96	0.65	0.62	1.21	0.51	0.62
1961	0.91	0.57	0.94	0.63	0.61	1.26	0.52	0.58
1962	0.96	0.52	0.96	0.57	0.55	1.18	0.44	0.55
1963	0.92	0.53	0.93	0.54	0.56	1.20	0.43	0.55
1964	0.96	0.54	0.95	0.55	0.53	1.19	0.42	0.54
1965	0.96	0.57	0.90	0.56	0.53	1.17	0.39	0.53
1966	0.92	0.62	0.93	0.58	0.54	1.27	0.41	0.52
1967	0.92	0.62	1.03	0.59	0.53	1.24	0.40	0.52
1968	0.93	0.62	0.98	0.62	0.53	1.27	0.40	0.51
1969	0.94	0.62	0.98	0.62	0.53	1.31	0.39	0.51
1970	0.97	0.61	0.96	0.64	0.55	1.38	0.39	0.51
1971	0.97	0.60	0.92	0.63	0.55	1.39	0.38	0.50
1972	0.96	0.60	0.92	0.63	0.56	1.38	0.40	0.50
1973	0.97	0.57	0.94	0.62	0.56	1.37	0.39	0.49
1974	0.99	0.59	0.96	0.60	0.55	1.37	0.38	0.49
1975	1.02	0.60	0.98	0.58	0.54	1.40	0.38	0.49
1976	1.01	0.58	0.90	0.58	0.54	0.40	0.37	0.45
1977	1.03	0.59	0.91	0.60	0.54	1.33	0.38	0.45
1978	1.03	0.62	0.92	0.58	0.54	1.35	0.38	0.46
1979	1.04	0.62	0.92	0.59	0.54	1.37	0.38	0.46
1980	1.04	0.64	0.92	0.60	0.55	1.39	0.36	0.45
1981	1.03	0.64	0.91	0.61	0.55	1.41	0.37	0.47
1982	1.02	0.65	0.93	0.59	0.56	1.47	0.37	0.47
1983	1.01	0.67	0.92	0.60	0.57	1.41	0.37	0.48
1984	1.01	0.87	0.93	0.62	0.58	1.45	0.38	0.47

The same is true for the most elite group of researchers, that in the academies. The number of science workers in the Union Academy was roughly equal to that of republican academies

ever since the early 1960s (Table 8-7).

Table 8-7. Distribution of science workers by republican academies, shares, %%.

Year	USSR	Ukraine	Belo-russia	Uzbek.	Kazakh.	Geor-gia	Azer-baid.
1959	58.52	8.28	3.16	4.65	3.79	5.27	4.07
1961	46.61	11.45	4.39	7.44	4.43	6.51	4.93
1963	49.73	13.11	3.33	5.32	4.29	6.01	5.30
1964	49.95	13.02	3.40	5.27	4.35	5.84	5.17
1965	49.41	13.47	3.76	4.97	4.61	5.86	4.95
1966	48.09	13.98	4.14	4.94	4.61	6.16	5.03
1967	49.58	13.76	4.21	4.63	4.51	5.79	5.03
1968	49.48	13.91	4.29	4.75	4.33	5.71	5.29
1969	49.14	14.00	4.38	4.67	4.28	5.81	5.07
1970	49.26	14.22	4.37	4.57	4.35	5.83	4.68
1971	48.66	14.17	5.05	4.42	4.20	5.87	4.88
1972	48.48	14.26	5.07	4.46	4.23	5.74	4.72
1973	47.35	14.22	5.91	4.40	4.25	5.92	4.98
1974	48.07	13.86	5.25	4.25	4.27	6.11	4.99
1975	47.98	13.88	5.32	4.24	4.28	6.30	4.84
1976	48.58	13.86	5.36	4.01	4.23	6.06	4.80
1977	49.04	13.50	5.43	4.04	3.97	5.98	4.75
1978	49.40	13.45	5.51	4.09	4.03	6.03	4.59
1979	49.34	13.71	5.59	4.09	4.26	5.52	4.65
1980	49.35	13.80	5.55	4.00	4.27	5.80	4.45
1981	49.27	13.76	5.54	4.18	4.25	5.70	4.49
1982	49.54	13.88	5.46	3.95	4.16	5.76	4.51
1983	49.98	14.11	5.41	3.94	4.16	5.53	4.53
1984	50.14	14.12	5.38	3.92	4.15	5.38	4.51

Source: NKh.

Table B-7. Continued.

Year	Lithuania	Moldavia	Latvia	Kirgizia	Tadjikistan	Armenia	Turkmenia	Estonia
1959	1.26	.69	2.07	1.38	1.79	2.65	1.18	1.26
1961	1.57	.84	2.56	1.70	1.49	3.06	1.51	1.53
1963	1.37	.95	2.20	1.41	1.45	3.04	1.27	1.23
1964	1.42	.96	2.33	1.54	1.42	2.96	1.21	1.17
1965	1.47	1.00	2.23	1.59	1.35	2.96	1.21	1.15
1966	1.44	1.04	2.07	1.67	1.49	3.06	1.15	1.14
1967	1.39	1.02	2.11	1.59	1.40	2.83	1.03	1.12
1968	1.44	1.00	2.06	1.57	1.35	2.78	1.00	1.05
1969	1.48	1.04	2.03	1.57	1.37	3.20	0.93	1.03
1970	1.60	0.97	2.07	1.59	1.36	3.09	0.97	1.08
1971	1.70	0.95	2.06	1.63	1.33	3.02	0.96	1.07
1972	1.77	0.96	2.12	1.63	1.35	3.17	0.98	1.06
1973	1.74	0.98	2.05	1.61	1.40	3.16	0.97	1.07
1974	1.75	1.01	2.04	1.68	1.45	3.24	0.95	1.08
1975	1.76	1.01	2.02	1.64	1.39	3.25	0.99	1.09
1976	1.76	1.01	1.91	1.65	1.43	3.28	1.00	1.08
1977	1.80	1.01	1.94	1.64	1.41	3.30	1.12	1.07
1978	1.79	1.03	1.92	1.54	1.35	3.22	1.00	1.06
1979	1.80	1.03	1.82	1.57	1.34	3.17	1.06	1.08
1980	1.78	1.09	1.79	1.56	1.37	3.09	1.00	1.10
1981	1.77	1.11	1.75	1.55	1.33	3.19	1.04	1.09
1982	1.81	1.11	1.70	1.52	1.32	3.13	1.05	1.10
1983	1.78	1.13	1.58	1.42	1.34	3.01	1.03	1.06
1984	1.79	1.09	1.54	1.44	1.44	3.03	1.02	1.07

To capture the results of the slight shifts in R&D resources among the republics, we computed an index of inventive productivity of science workers with fixed 1976 productivity levels by republic (see Table B-8).[10] This index reflects the change in average national inventive productivity due to the interrepubli-

[10] Multiplied the shares of science workers in republics (Table B-7) by their respective number of patents per thousand science workers in 1976 (Table B-1), and added the fifteen series together, then converted to an index based in 1976.

Table B-8. Index of Inventive Productivity of Science Workers Reflecting Interrepublican Shifts, 1976 = 100.

Year	
1950	99.16
1951	
1952	
1953	99.15
1954	
1955	99.21
1956	99.07
1957	98.70
1958	98.33
1959	98.24
1960	98.52
1961	98.61
1962	99.25
1963	99.47
1964	99.77
1965	99.89
1966	99.54
1967	99.64
1968	99.51
1969	99.48
1970	99.45
1971	99.50
1972	99.56
1973	99.72
1974	99.85
1975	99.96
1976	100.00
1977	100.10
1978	100.14
1979	100.20
1980	100.24
1981	100.18
1982	100.20
1983	100.09
1984	101.71

Source: Tables B-1 and B-6.

can shifts in the number of science workers only. The index confirms high stability of the shares. It declines by about 0.7% over the 1950s, then rises by about 3.2% in 1961-84. Increase of 2.5% over 35-year period is too negligible to be considered as a

positive factor in the change of R&D productivity.

The presence of the relatively less-productive regional science establishments in the USSR explains part of the difference in R&D performance with other countries, whith more homogenous R&D sectors. But it cannot explain the deterioration in productivity over time, since the share of these regions is no larger now than it was in the early 1950s.[11]

---

[11]Underlying the stability of the shares of republics in R&D inputs is the apparent stability (or even increase) of the share of a few largest cities, practically all of them in Russia and Ukraine; see Kanygin, et al., 1979, p. 26.

APPENDIX C. SOURCES AND TABLES.

Sources for Table 4-1, number of prototypes of machines, equipment and instruments.

1984 - NKh-84,
1980-3 - NKh-83, 100-101.
NKh-79, 112; NKh-78, 94; NKh-77, 98; NKh-76, 148; NKh-75, 171; NKh-74, 150; NKh-73, 185; NKh-72, NKh-71, 113 - used for calculating 1971-9.
1960, 1965, 1968-9, and 1950 (a) - NKh-69, 230-231;
1966-7 - NKh-67, 268-9;
1958, 1960, 1962-3 - NKh-63, 171;
a, 1956-7, 1959 - NKh-59, 155; a, 1951-5 - NKh-58, 157.

Sources for Table A-1. Number of science workers.

1970, 1975, 1980-3 - NKh-83, 94; 1976-9 - NKh-80, 95. 1971-4 - NKh-74, 143; 1962-3 - NKh-63, 589; 1964 - NKh-65, 713. 1954-6 -NKh-56, 257; 1953, 1957-8 - NKh-58, 843; 1959 - NKh-59, 754; 1968-9 - NKh-7; 1953, 1950, 196NKh-58, 843; 1959 - NKh-59, 1961 -NKh-61, 705. 1950, 1960, 1965-7 - NKh-67, 812; Note: Science workers in 1954-6 are for Oct. 1.

Table C-1. Science workers - women, thousands, year-end.

Year	Total	Doctors	Candi-dates	Academy members, professors	Docents	SNS	MNS, assis-tants
1950	59.0	0.6	11.4	0.5	3.2	3.5	9.4
1955	81.6			0.6	4.8	4.4	8.9
1956	87.0			0.6	5.1	4.7	9.3
1957	93.7			0.6	5.4	5.0	11.3
1958	101.4			0.7	5.5	5.0	12.5
1959	111.1			0.7	5.8	5.4	13.5
1960	128.7	1.1	28.8	0.7	6.2	5.8	13.6
1961	150.0			0.8	6.7	6.0	14.5
1962	177.7			0.9	7.3	7.1	22.7
1963	204.8			1.0	8.8	7.9	25.2
1964	230.2			1.1	9.5	8.3	25.0
1965	254.8	1.4	34.8	1.1	9.5	8.3	25.0
1966	273.5	2.0	41.0	1.2	10.6	8.6	22.9
1967	294.9	2.2	45.4	1.3	11.6	9.0	22.9
1968	318.7	2.5	50.7	1.5	12.6	9.6	24.0
1969	343.2	2.9	55.4	1.6	14.0	10.2	24.2
1970	359.9	3.1	60.7	1.8	14.4	9.8	24.3
1971	388.5	3.5	68.0	2.0	15.6	10.4	24.7
1972	414.0	3.7	73.7	2.1	16.9	10.8	23.4
1973	439.5	4.0	79.6	2.2	17.8	11.5	23.3
1974	464.6	4.4	83.7	2.3	18.8	12.1	22.9
1975	488.3	4.5	94.0	2.4	19.6	12.5	22.3
1976	497.9	4.8	97.4	2.5	21.2	13.1	21.6
1977	511.6	5.1	101.0	2.7	22.4	13.6	21.2
1978	522.5	5.2	104.2	2.8	23.9	14.2	20.3
1979	531.1	5.2	107.5	2.9	25.2	14.4	20.2
1980	548.1	5.2	111.1	3.0	26.3	14.9	19.1
1981	562.5	5.4	115.1	3.1	27.6	15.3	17.9
1982	574.2	5.5	118.2	3.1	29.3	15.9	18.3
1983	577.3	5.6	123.2	3.2	30.9	16.5	18.9

Sources: 1960, 1970, 1975, 1980-3 - NKh-83, 96; 1950, 1965, 1976-9 - NKh-80, 95; 1971-4 - NKh-74, 144; 1969 - NKh-70, 657; 1968 - NKh-69, 695; 1966-7 - NKh-68, 695; 1964 - NKh-65, 710; 1963 - NKh-64, 700; 1962 - NKh-63, 590; 1961, 1959, 1958 - NKh-61, 703. 1956, 1957 - NKh-59, 755; 1955 - NKh-56, 261.
Note: Col. d in 1961 and before - only professors.

Table C-2. Science workers by degree and rank, thousand, year-end.

Year	Science workers without rank & degree	Doctors	Candidates	Academy members, professors	Docents	SNS	MNS, assistants
1950	47.01	8.3	45.5	8.9	21.8	11.4	19.6
1953	58.00	8.5	59.5	8.5	24.7	12.9	19.8
1954	66.20	9.0	69.2	8.8	26.8	14.0	16.2
1955	67.10	9.5	78.0	9.0	28.6	14.6	17.1
1956	71.48	9.8	85.7	9.1	30.4	15.6	17.8
1957	85.40	10.0	87.2	9.4	31.6	16.7	21.3
1958	100.64	10.3	90.0	9.6	32.7	17.2	23.6
1959	116.82	10.5	94.0	9.7	34.3	18.4	26.3
1960	122.06	10.9	98.3	9.9	36.2	20.3	26.7
1961	192.13	11.3	102.5	10.3	38.2	21.0	28.7
1962	283.50	11.9	108.7	11.0	40.6	23.8	45.0
1963	310.06	12.7	115.2	11.4	42.9	25.8	47.9
1964	340.96	13.7	123.9	12.0	46.0	27.2	48.2
1965	376.68	14.8	134.4	12.5	48.6	28.7	48.9
1966	399.22	16.6	152.4	13.6	52.8	30.2	47.6
1967	432.11	18.3	169.3	14.7	56.9	32.4	46.3
1968	456.61	20.0	186.4	15.9	60.9	35.1	48.0
1969	488.70	21.8	205.4	16.9	64.9	37.3	48.4
1970	505.10	23.6	224.5	18.1	68.6	39.0	48.8
1971	543.30	26.1	249.2	19.5	73.2	42.4	49.2
1972	567.90	28.1	269.5	20.6	77.0	45.4	47.5
1973	593.40	29.8	288.3	21.6	80.5	47.8	47.1
1974	624.50	31.7	309.5	22.5	84.4	50.7	46.4
1975	655.20	32.3	326.8	22.9	87.9	53.3	45.0
1976	656.40	34.6	345.4	24.0	92.5	56.3	44.3
1977	660.80	36.0	358.4	25.3	96.6	59.3	43.2
1978	674.90	36.6	371.2	26.1	101.4	61.4	42.4
1979	681.10	37.1	383.6	26.9	105.8	63.8	42.3
1980	694.20	37.7	396.2	27.4	110.7	66.0	41.1
1981	710.20	38.7	409.7	28.1	115.7	68.6	40.2
1982	707.50	39.7	423.0	28.7	121.3	70.9	40.6
1983	693.30	41.0	435.4	29.4	125.4	73.5	42.0

Sources: 1950, 1960, 1970, 1975, 1980-3 - NKh-83, 94; 1965, 1976-9 - NKh-80, 95; 1971-4 - NKh-74, 143; 1968-9 - NKh-69, 694; 1966-7 - NKh-67, 809; 1958, 1962-3 - NKh-63, 589; 1956-9 - NKh-59, 755; 1953, 1955 - NKh-58, 843; 1954 - NKh-56, 257; 1964 - NKh-65, 709; 1961 - NKh-61, 702;

Note: at least through 1956, and possibly through 1959, the data are for Oct. 1.

Table C-3. The number of samples of new machines, equipment, and apparatus created per year by group.

Year	Metal cutting machine tools	Forges & presses	Casting machines	Mining & metallurgy equip.	Fuels industry equip.	Power generation	Electrotechnical equip.
1950	133	51	8	44	35	42	48
1951	140	16	13	28	72	25	33
1952	181	46	3	28	52	11	58
1953	208	53	2	22	28	26	33
1954	144	65	7	35	40	43	52
1955	193	78	11	12	25	19	30
1956	258	110	19	43	77	39	17
1957	253	85	12	83	77	39	146
1958	245	99	19	122	135	65	212
1959	301	78	27	122	129	74	212
1960	201	140	37	171	156	103	313
1961	275	101	40	174	202	74	525
1962	249	141	48	157	106	94	438
1963	238	120	42	118	139	67	514
1964	263	102	35	113	101	90	516
1965	281	106	59	115	141	51	537
1966	301	73	54	146	141	31	527
1967	252	87	57	121	115	43	490
1968	290	73	40	80	52	63	488
1969	333	96	28	126	38	52	543
1970	361	99	51	95	42	49	565
1971	352	92	57	91	49	47	506
1972	430	115	32	121	77	58	572
1973	370	112	50	129	18	75	527
1974	348	107	29	151	44	53	484
1975	372	110	35	81	50	89	556
1976	347	117	31	95	66	42	504
1977	361	87	37	88	61	53	395
1978	353	124	43	77	55	55	426
1979	302	109	39	95	64	33	455
1980	283	173	36	105	18	53	396
1981	267	132	42	82	28	53	367
1982	251	121	40	111	3	44	502
1983	303	96	35	121		50	456
1984	261	78	36	120		49	404
1985	266	60	35	96		56	385

Table C-3. Continued.

Year	Transport & lifting equipm.	Automobiles, tractors, autotractor equip.	Agricultural machines	Chemical, pump, & compressor equip.	Construction, earthmoving, construction materials	Wood-processing & paper-making equipm.	Light-industry equip.
1950	33	15	53	53	47	8	39
1951	31	7	66	24	30	27	16
1952	54	17	55	35	22	23	36
1953	22	8	87	39	19	9	86
1954	74	13	59	43	36	25	168
1955	101	16	55	82	118	35	115
1956	127	38	69	159	122	42	219
1957	139	46	70	166	133	54	89
1958	141	51	127	153	165	43	118
1959	133	59	146	228	154	38	144
1960	138	66	204	398	189	86	174
1961	239	190	253	416	199	75	203
1962	205	115	232	461	146	61	115
1963	225	52	211	378	177	36	154
1964	218	59	144	370	161	37	122
1965	214	43	115	307	188	58	146
1966	206	43	93	481	174	54	199
1967	128	52	124	355	127	53	173
1968	116	26	72	286	109	37	110
1969	143	41	68	263	125	59	134
1970	121	32	85	268	147	51	86
1971	127	53	92	301	104	63	107
1972	153	50	105	320	93	55	99
1973	143	52	119	290	104	62	123
1974	127	51	105	263	90	72	116
1975	124	26	89	276	119	42	132
1976	114	28	73	243	129	45	115
1977	111	19	86	252	119	41	93
1978	190	38	82	230.	88	61	86
1979	124	18	97	283	111	39	103
1980	121	39	101	228	87	28	92
1981	115	27	69	205	83	42	87
1982	77	31	58	212	94	38	106
1983	79	76	86	245	113	20	113
1984	39	88	123	238	125	29	110
1985	66	77	127	223	79	45	122

Table C-3. Continued.

Year	Construction & road-building machines	Equipment for construction materials industry	Equipment for food-processing industry	Printing equipment	Welding & autogenous equipm.	Radio & communications equipment
1950			7			
1951			11			
1952			16			
1953			31			
1954			64			
1955			92			
1956			131			
1957			82			
1958			105			
1959			92			
1960			255			
1961			219			
1962			196			
1963			206			
1964			129			
1965	111	77	158			
1966			171			
1967			131			
1968	79	30	97			
1969	69	56	105			
1970	79	68	152			
1971	64	40	134	12	56	117
1972	52	41	122	14	82	136
1973	65	39	126	10	33	140
1974	59	31	153	11	57	108
1975	78	41	89	22	77	115
1976	77	52	83	24	53	165
1977	83	36	82	17	60	
1978	61	27	146	34	64	
1979	76	35	111	18	73	
1980	52	35	105	28	62	
1981	60	23	90	22	62	
1982	71	23	111	18	83	
1983	66	47	156	12		
1984	80	45	130	17		
1985	54	25	139	15		

Sources: 1950-7 - NKh-58, 157; 1958-9 - NKh-59, 155; 1962-3 - NKh-63, 171; 1960, 1965, 1968-9 - NKh-69, 231; 1966-7 - NKh-67, 269;
1980-83 - NKh-83, 100; fuels industry equipment in 1980-2 - NKh-82, 93; 1964 - NKh-65, 205.

BIBLIOGRAPHY

Aganbegian, A. G., "Neprostye shagi perestroiki", Nedelia, no. 1, 1987.

Agursky, Michael, The Research Institute of Machine-Building Technology. Soviet Insitutions Series Paper no. 8. Soviet and East European Research Centre, Hebrew Univeristy, Jerusalem, Sept. 1976.

Aleksandrova, V. P., et al., eds., Effektivnost' novoi tekhniki (Na primere promyshlennosti Ukrainskoi SSR). Kiev: Naukova dumka, 1977.

Amann, Ronald, Cooper, Julian, and Davies, R. W., eds., Technological Level of Soviet Industry. New Haven, Conn.: Yale University Press, 1977.

Amann, Ronald, and Cooper, Julian, eds., Industrial Innovation in the Soviet Union. New Haven, Conn.: Yale University Press, 1982.

Amirov, Iu. D., Organizatsiia i effektivnost' nauchno-issledovatel'skikh i opytno-konstruktorskikh rabot. Moscow: Ekonomika, 1974.

Anchishkin, A., "Novoe kachestvo ekonomicheskogo rosta", Voprosy ekonomiki, no. 9, 1986.

Anchishkin, A. I., Nauka-tekhnika-ekonomika. Moscow: Ekonomika, 1986.

Andreev, Nikolai, "Attestatsiia: protiv negodnykh ili protiv neugodnykh?", Literaturnaia gazeta, no. 41, Oct. 8, 1986.

Andriushchenko, A., "Pochemu mal vklad?", Pravda, Oct. 3, 1985.

Anisimov, G. D., et al., eds., Nauchno-tekhnichesky progress i khoziaystvennaya reforma. Moscow: Nauka, 1969.

Arakelian, Iu., and Gubarev, V., "Povyshaia trebovatel'nost'", Pravda, Jan. 27, 1986.

Arkhangel'skii, V. N., Planirovanie i finansirovanie nauchnykh issledovanii. Moscow: Nauka, 1976.

Arkhangel'skii, V. N., Territorial'noe upravlenie razvitiem nauki i tekhniki. Moscow: Ekonomika, 1985.

Arrow, Kenneth J., "The Organization of Economic Activity: Issues Pertinent to the Choice of Market versus Nonmarket Allocation", in: U. S. Congress, Joint Economic Committee, The Analysis and Evaluation of Public Expenditure: The PPB System. vol. 1. Washington, DC: Government Printing Office, 1969.

Artem'ev, E. I., and Kravets, L. G., Izobtreteniia-Uroven' tekhniki-Upravlenie. Second edition. Moscow: Ekonomika, 1977.

Artem'ev, E. I., and Kravets, L. G., "Izobtreteniia i uroven' tekhniki", Ekonomika i organizatsiia promyshlennogo proizvodstva, no. 1, 1979.

Azbel', Mark, "Pis'ma iz Izrailia. Pis'mo pervoe: nauka po ievreiski i nauka po-amerikanski", Dvadtsat' dva, no. 39, Nov.-Dec. 1984.

Babanin, B., "Tormoz vmesto stimula", Sotsialisticheskaia indus-

triia, June 21, 1986.

Bachurin, A. V., Intensifikatsiia i effektivnost'. Moscow: Ekonomika, 1985.

Bashin, M. L., Effektivnost' fundamental'nykh issledovanii. Moscow: Mysl', 1974.

Bekleshov, V. K., Mintairov, M. S., Puzynia, K. F., and Saraev, Iu. D., Organizatsiia i planirovaniie deiatel'nosti otraslevykh NII i KB v priborostroenii. Moscow: Mashinostroenie, 1986.

Beliaev, E. A., and N. S. Pyshkova, Formirovanie i razvitie seti nauchnykh uchrezhdenii SSSR. Moscow: Nauka, 1979.

Beliakov, V., "Nakhodit tot, kto ishchet", Pravda, March 12, 1986.

Belousov, V. I., "Pochemu novatsii ne vstrechaiut ovatsii?", Ekonomika i organizatsiia promyshlennogo proizvodstva, no. 8, 1980.

Bergson, Abram, and Herbert S. Levine, eds., The Soviet Economy: Toward the Year 2000. London: George Allen & Unwin, 1983.

Bergson, Abram, "Technological Progress", in: Bergson and Levine, 1983.

Berliner, Joseph S., The Innovation Decision in Soviet Industry. Cambridge, Ma.: MIT Press, 1976.

Berliner, Joseph S., "Planning and Management", in: Abram Bergson and Herbert S. Levine, eds., The Soviet Economy Towards the Year 2000. London: George Allen and Unwin, 1983.

Berliner, Iu., "Organizatsiia nauchnykh issledovanii v otrasli", Planovoe khoziaistvo, no. 6, 1982.

Berry, M. J., "Towards an inderstanding of R and D and innovation in a planned economy: the experience of the machine tool industry.", in: Amann and Cooper, 1982.

Berry, M. J., and Julian Cooper, "Machine Tools", in: Amann, Cooper, and Davies, 1977.

Beshelev, S. D., and F. G. Gurvich, Nevospolnimyi resurs. Moscow: Nauka, 1986.

Bliakhman, L. S., Ekonomika nauchno-tekhnicheskogo progressa. Moscow: Vysshaia shkola, 1979.

Bliakhman, L. S., and Mintairov, M. S., eds., Normativnye osnovy planirovaniia nauchno-tekhnicheskogo progressa. Leningrad: Nauka, 1981.

Bliokov, E. N., "Vnedrenie dostizhenii akademicheskoi nauki v praktiku", Vestnik AN SSSR, no. 8, 1984.

Bogatko, S., "Urok Ieniseia", Pravda, 22 Oct. 1985.

Bogaev, A. A., Dobrov, G. M., and V . N. Klimeniuk, "Prognozirovanie urovnia nauchnogo potentsiala USSR", Naukovedenie i informatika, issue 5, 1972.

Bogaev, A. A., and A. A. Savel'ev, "Voprosy regulirovaniia chislennosti personala i stimulirovaniia nauchnogo truda", Naukovedenie i informatika, issue 23. Kiev: Naukova dumka, 1982.

Bogoliubov, K. M., and Smirtiukov, M. S., eds., Resheniia partii i pravitel'stva po khoziaistvennym voprosam: Sbornik dokumentov. vol. 14. Moscow: Politizdat, 1983.

Bol'shaia Sovetskaia Entsyklopediia. 3rd edition. Vol. 17. Moscow: Sovetskaia entsyklopediia, 1974.
Bornstein, M., et al., _The Planning and Management of Industrial Research and Development in the USSR._ Washington, DC: NSF, 1980.
Bound, John, Cummins, Clint, Griliches, Zvi, Hall, Bronwyn H., and Jaffe, Adam, "Who Does R&D and Who Patents?", in: Griliches, 1984.
Bratchikov, N., "Po pravu pervootkryvatelei", _Pravda_, Dec. 18, 1986.
Budavei, V. Iu., and Panova, M. I., _Ekonomicheskiie problemy tekhnicheskogo progressa._ Moscow, 1974.
Burke, Clare E., and D. de S. Price, "The Distribution of Citations from Nation to Nation on a Field by Field Basis - a Computer Calculation of the Parameters", _Scientometrics_, vol. 3, no. 5, 1981.
Byk, I. S., " Problemy effektivnogo isplo'zovaniia nauchnogo potentsiala vuzov", _Naukovedenie i informatika_, no. 12, 1974.
Byk, I. S., "Nauchnye issledovaniia v vysshei shkole", _Naukovedenie i informatika_, no. 22, 1981.
Bykov, V. A., "Intellektual'nyi potentsial konstruktora", _Ekonomika i organizatsiia promyshlennogo proizvodstva_, no. 2, 1981.
Campbell, Robert W., _Reference Source on Soviet R&D Statistics 1950 - 1978._ Washington, DC: National Science Foundation, 1978.
Campbell, Robert W., _Soviet R&D Statistics 1977 - 1980._ Washington, DC: National Science Foundation, 1980.
Chemodanov, M. P., "O metodakh opredeleniia tempov razvitiia nauki", in: Akademiia Nauk SSSR. Sibirskoe otdelenie. _Fundamental'nye i prikladnye issledovaniia v usloviiakh NTR._ Novosibirsk: Nauka, 1978.
Chemodanov, M. P., "Faktor intensifikatsii v razvitii nauki", in: Akademiia Nauk SSSR. Sibirskoe otdelenie. _Fundamental'nye i prikladnye issledovaniia v usloviiakh NTR._ Novosibirsk: Nauka, 1978.
Cherednichenko, G. A., and Shubkin, V. N., _Molodezh vstupaet v zhizn'._ Moscow: Mysl', 1985.
Cherniak, A., "Perestroika", _Pravda_, July 16, 1985.
Chertkov, V., "Tiazhba o voznagrazhdenii", _Pravda_, Oct. 17, 1985.
Chubarenko, A. I., Shalimov, V. E., and Kolesnikov, A. S., _Ekonomicheskoe upravlenie nauchno-tekhnicheskim progressom. Spravochnoe posobie._ Moscow: Ekonomika, 1985.
Chubarov, K., "Ideia ne po profiliu", _Pravda_, Oct. 19, 1984.
Chudesova, G. P., "Organizatsionnye i sotsiologicheskie problemy sootnosheniia mobil'nosti i stabil'nosti konstruktorov otraslevogo NII", in: _Nauka i tekhnika (voprosy istorii i teorii)_ issue VIII, part I, Leningrad, 1973.
Cocks, Paul, _Science Policy in the Soviet Union._ Washington, DC: NSF, 1980.
Cocks, Paul, "Organizing for Technological Innovation in the

1980s", in: Gregory Guroff and Fred V. Carstensen, eds., Entrepreneurship in Imperial Russia and the Soviet Union. Princeton, NJ: Princeton University Press, 1983.
Comanor, William S., and F. M. Scherer, "Patent Statistics as a Measure of Technical Change", Journal of Political Economy, vol. 77, Dec. 1969.
Cooper, Julian, "The Scientific and Technical Revolution in Soviet Theory", in: Frederic J. Fleron, Jr., ed., Technology and Communist Culture: The Socio-Cultural Impact of Technology under Socialism. New York: Praeger, 1977.
Cooper, Julian, "Innovation for innovation in Soviet industry", in: Amann and Cooper, 1982.
Danilov, B. F., "S tochki zreniia izobretatelia", Ekonomika i organizatsiia promyshlennogo proizvodstva, no. 12, 1980.
Denisov, V., "Stimuly inzhenernogo truda", Ekonomicheskaia gazeta, no. 29, July 1985.
Derevianko, A. P., and S. S. Kutateladze, eds., Metodologicheskie problemy sovershenstvovaniia vzaimodeistviia nauki i proizvodstva. Novosibirsk: Nauka, 1985.
Dobrov, G. M., Klimeniuk, V. N., Smirnov, L. P, and Savel'ev, A. A., Potentsial nauki. Kiev: Naukova dumka, 1969.
Dronov, F. A., and Shatokhina, M. N., eds., Ekonomika osvoeniia novoi produktsii. Minsk: Nauka i tekhnika, 1970.
Dronov, F. A., Planirovanie i prognozirovanie nauchno-tekhnicheskogo progressa. Minsk: Nauka i tekhnika, 1974.
Dudkin, L. M., and M. A. Shimanovich, "O predlagaiemoi sisteme priznaniia izobretenii", Ekonomika i organizatsiia promyshlennogo proizvodstva, no. 12, 1980.
Duzhenkov, V. I., "Problemy razvitiia i razmeshcheniia nauki v soiuznykh respublikakh", Nauka i tekhnika (voprosy istorii i teorii). Issue VII, second part. Leningrad: Institute of history of science and technology, Leningrad division, 1972.
Dzhanoian, O., "Ne chislom ..", Sotsialisticheskaia industriia, April 29, 1986.
Efimov, K. A., Semin, S. I., and E. E. Troitskaia, Ekonomicheskie problemy NTP v promyshlennosti. Moscow: Ekonomika, 1985
"Ekonomicheskie rychagi - v deistvie", Pravda, Oct. 8, 1986.
Evenson, Robert E., "International Invention: Implications for Technology Market Analysis", in: Griliches, 1984.
Fabrichev, P., "Odnoobrazie na liuboi vkus", Ekonomicheskaia gazeta, no. 32, August 1978.
Fal'tsman, V. K., "Mashinostroenie: puti peremen", Ekonomika i organizatsiia promyshlennogo proizvodstva, no. 12, 1985.
Feshbach, Murray and Louvan E. Nolting, "Statistics on Research and Development Employment in the USSR". International Population Reports. Series P-95, no. 76. Washington, DC: US Department of Commerce, Bureau of the Census, June 1981.
Fomin, B., "Stimul k tvorchestvu", Pravda, Jan. 31, 1985.
Fomin, B., "Lavry i ternii", Pravda, Spet. 5, 1985a.
Fomin, B., "Ne mnogo li kontor", Pravda, May 4, 1986.
Foniakov, Ilia, "Pribavka k zarplate", Literaturnaia gazeta, Oct. 3, 1984.

Fox, Mary Frank, "Publication Productivity among Scientists: A Critical Review", Social Studies of Science, vol. 13, 1983.

Frame, J. D., and D. R. Prokrym, "Counts of U.S. and Soviet Science and Technology Journals", Scientometrics, vol. 3, no. 3, 1981.

Fusfeld, Herbert I., and Richard N. Langlois, Understanding R&D Productivity. New York: Pergamon Press, 1982.

Gatovskii, L. M., Ekonomicheskie problemy nauchno-tekhnicheskogo progressa. Moscow: Nauka, 1971.

Ginzburg, V. L., "Neskol'ko zamechanii ob uskorenii nauchno-tekhnicheskogo progressa i uluchshenii raboty Akademii nauk SSSR", Vestnik AN SSSR, no. 4, 1986.

Gladkov, N., "Kuda poidut 30 millionov", Feb. 2, 1987.

Glagoleva, G., "Razvitie opytnykh proizvodstv", Ekonomicheskaia gazeta, no. 29, 1983.

Glavatskii, "Napravleniia korennoi perestroiki", Ekonomika i organizatsiia promyshlennogo proizvodstva, no. 4, 1982.

"Glavnyi rychag intensifikatsii", Pravda, March 19, 1986.

Gliazer, L. S., "Novaia situatsiia v nauke", Ekonomika i organizatsiia promyshlennogo proizvodstva, no. 4, 1971.

Gliazer, L. S., "Oplata truda v nauke: problemy i eksperimenty", Ekonomika i organizatsiia promyshlennogo proizvodstva, no. 4, 1975.

Gliazer, L. S., "Nauka i proizvodstvo: etapy stanovleniia sistemy", Ekonomika i organizatsiia promyshlennogo proizvodstva, no. 4, 1975.

Golland, E. B., "V zashchitu chetvertoi sistemy", Ekonomika i organizatsiia promyshlennogo proizvodstva, no. 2, 1981.

Goloshchapov, V. N., F. S. Kontorovich, V. A. Prianishnikov, and L. A. Flerov, "O sovremennom sostoianii nauchnogo priborostroeniia", Naukovedenie i informatika, no. 12, 1974.

Golosovskii, S. I., Effektivnost' nauchnykh issledovanii. Moscow: Ekonomika, 1969.

Golosovskii, S. I., Ekonomicheskaia effektivnost' issledovanii i razrabotok. Moscow: Moskovskii rabochii, 1973.

Golosovskii, S. I., Grinchel' B. M., Izmerenie vliianiia nauchno-tekhnicheskogo progressa na effektivnost' obshchestvennogo proizvodstva. Moscow: Nauka, 1981.

Gorbachev, M. S., "Rech' General'nogo sekretaria TsK KPSS M. S. Gorbacheva na vstreche s partiinym aktivom Krasnodarskogo kraia", Pravda, Sept. 20. 1986.

Gordeeva, N. A., Vzaimosviazi akademicheskoi nauki i proizvodstva. Moscow: Nauka, 1985.

Gorokhov, V., "Tok 'maloi' energetiki", Pravda, May 18, 1986.

Gosplan SSSR, Metodicheskie ukazaniia k razrabotke gosudarstvennykh planov razvitiia narodnogo khoziaystva SSSR. Moscow: Ekonomika, 1974.

Griliches, Zvi, ed., R&D, Patents, and Productivity. Chicago: University of Chicago Press, 1984.

Grinchel', B. M., Izmerenie effektivnosti nauchno-tekhnicheskogo progressa. Moscow: Ekonomika, 1974.

Grishaev, Ie. Ie., "Voprosy finansirovaniia nauchnykh issledova-

nii", in: Sotsialno-ekonomicheskie i organizatsionnye voprosy nauki v SSSR. part 2. Moscow: 1970.
Gvishiani, D. M., et al., eds., Nauchno-tekhnicheskaia revolutsiia i izmenenie struktury nauchnykh kadrov SSSR. Moscow: Nauka, 1973.
Gvishiani, D. M., ed., Osnovnye printsipy i obshchie problemy upravleniia naukoi. Moscow: Nauka, 1973.
Gukasov, G., "O stepeniakh i rannem vzlyete", Izvestiia, June 21, 1984.
Gusev, O., "Khotia net protivnikov ...", Pravda, June 3, 1986.
Gustafson, Thane, "Why Doesn't Soviet Science Do Better Than It Does?", in: Lubrano and Solomon, 1980.
Gustafson, Thane, Selling the Russians the Rope? Soviet Technology and US Export Controls. R-2649-ARPA. Santa Monica, Ca.: Rand Corporation, April, 1981.
Gvishiani, D. M., ed., Osnovnye printsipy i obshchie problemy upravleniia naukoi. Moscow: 1973.
Hanson, Philip, "The Soviet system as a recipient of foreign technology", in: Amann and Cooper, 1982.
Hanson, Philip, "The End of Import-Led Growth? Some Observations on Soviet, Polish, and Hungarian Experience in the 1970s", Journal of Comparative Economics, vol. 6, no. 2, 1982a.
Hanson, Philip, Bulletin of Atomic Scientists, 1987.
Hoffmann, Eric, "Soviet Views of `The Scientific-Technological Revolution`", World Politics vol. 30, July 1978.
Holloway, David, "Innovation in the defence sector", in: Amann and Cooper, 1982.
Iadov, V. A., ed., Sotsial'no-psikhologicheskii portret inzhenera. Moscow: Mysl', 1977.
Iakovets, Iu. V., Zakonomernosti nauchno-tekhnicheskogo progressa i ikh planomernoe ispol'zovanie. Moscow: Ekonomika, 1984.
Iampol'skii, S. M., S. G. Galuza, Ekonomicheskie problemy upravleniia nauchno-tekhnicheskim progressom. Kiev, 1976.
Iampol'skii, S. M., ed., Uskorenie nauchno-tekhnicheskogo progressa i intensifikatsiia vosproizvodstva osnovnykh fondov. vol. 2. Kiev: Naukova dumka, 1984.
Iankevich, W. F., "Analysis of Publication and Invention Productivity in Some Soviet Academic Institutions", Scientometrics, vol. 4, no. 6, 1982.
Ianson, E. Zh., Teoriia i praktika normirovaniia truda v otraslevykh nauchno-tekhnicheskikh organizatsiiakh. Leningrad: Leningrad University, 1985.
Ibragimova, Zamira, "Tiazhkii put' vnedreniia", Ekonomika i organizatsiia promyshlennogo proizvodstva, no. 5, 1973.
Iefimovskaia, V. M., "O formirovanii natsional'nykh nauchnykh kadrov v SSSR", in: Nauka i tekhnika (voprosy istorii i teorii), issue VII, part I, Leningrad: 1972.
Ieliutin, V. P., "Sovetskaia vysshaia shkola idet po leninskomu puti", Vestnik vysshei shkoly no. 4, 1970.
Ieliutin, V. P., "Sovetskaia nauka i zadachi vysshei shkoly", in: Iu. A. Ovchinnikov, ed., Sotsial'no-ekonomicheskie i mirovozzrencheskie problemy razvitiia sovetskoi nauki.

Moscow: Nauka, 1986.
"Iel'tsin vystupaet pered propagandistami", Novoye Russkoye Slovo, Aug. 1, 1986.
Iesil'baev, T., Petrushov, A., "Ne chastnyi sluchai", Pravda, Aug. 20, 1986.
Ignatov, L. A., "Vozrastnoi faktor v izobretatel'skom tvorchestve", Naukovedenie i informatika issue no. 8, 1973.
Il'ichev, V., "Okeanskii forpost nauki", Pravda, oct. 16, 1986.
"Inzhenernyi tsentr", Ekonomicheskaia gazeta, no. 35, Aug. 1985.
Iuzefovich, G. K., Nauka pri sotsializme: politiko-ekonomicheskie problemy. Leningrad: Leningrad university, 1980.
Jewkes, John, David Sawers, and Richard Stillerman, The Sources of Invention. New York: St. Martin's Press, 1958.
Joravsky, David, "The Stalinist Mentality and the Higher Learning", Slavic Review, vol. 42, no. 4, Winter 1983.
Kachanov, E., "Za chto platit' konstruktoru?", Ekonomicheskaia gazeta, no. 15, Apr. 1986.
Kamenitser, S. E., and Rusinov, F. M., eds., Organizatsiia i upravlenie deiatel'nost'u promyshlennykh predpriiatii. Second ed. Moscow: Vysshaia shkola, 1984.
Kanygin, Iu. M., A. Mironenko, and P. Danilovtsev, Zavodskie sluzhby vnedreniia (nauchno-issledovatel'skaia i opytno-eksperimental'naia baza predpriiatii). Novosibirsk, 1972.
Kanygin, Iu. M., Nauchno-tekhnicheskii potentsial. Novosibirsk: Nauka, 1974.
Kanygin, Iu. M., Danilovtsev, P. A., Tsykl "nauka-proizvodstvo": granitsy, struktura, puti uskoreniia. Novosibirsk: Nauka, 1976.
Kanygin, Iu. M., "Problemy intensifikatsii nauki", in: Akademiia Nauk SSSR. Sibirskoe otdelenie. Fundamental'nye i prikladnye issledovaniia v usloviiakh NTR. Novosibirsk: Nauka, 1978.
Kanygin, Iu. M., Botwin, V. A., and M. G. Dobrov, "Nauchnyi potentsial krupnogo goroda", Naukovedenie i informatika, no. 20, 1979.
Karagedov, R. G., "Ob organizatsionnoi strukture upravleniia promyshlennostiu", Ekonomika i organizatsiia promyshlennogo proizvodstva, no. 8, 1983.
Kashuba, B., "Zaboty konstruktorov", Ekonomicheskaia gazeta, no. 12, March 1978.
Kassel, Simon, and Cathleen Campbell, The Soviet Academy of Sciences and Technological Development. R-2533-ARPA. Santa Monica, CA: Rand Corporation, 1980.
Katser, M. A., "Mozhet byt', stoit uprostit'?", Ekonomika i organizatsiia promyshlennogo proizvodstva, no. 1, 1983.
"Kazhdyi dlia sebia", Sotsialisticheskaia industriia, April 29, 1986.
Kelle, V. Zh., and Mikulinskii, S. R., eds., Sotsiologicheskie problemy nauki. Moscow: Nauka, 1974.
Kelle, V. Zh., S. A. Kugel', and N. I. Makeshin, "Sotsiologicheskie aspekty organizatsii truda nauchnykh rabotnikov v sfere fundamental'nykh issledovanii (po materialam konkretno-sotsiologicheskogo issledovaniia)", in: V. Zh. Kelle, ed.,

Sotsiologicheskie problemy nauchnoi deiatel'nosti. Moscow: ISI AN SSSR, 1978.

Kharin, V. D., "Ne za stepen', a za trud", Literaturnaia gazeta, Jan. 15, 1986.

Khodyrev, V. E., "K voprosu o soderzhanii truda nauchno-pedagogicheskikh kadrov v tekhnicheskikh vuzakh", in: Nauka i tekhnika (voprosy istorii i teorii) issue VIII, part I, Leningrad, 1973.

Khurshudov, A., "Otraslevaia nauka: puti perestroiki", Sotsialisticheskaia industriia, March 25, 1986.

Kiselev, Iu. M., "Osobennosti opytnogo proizvodstva", Ekonomika i organizatsiia promyshlennogo proizvodstva. no. 3, 1986.

"Kliuchevaia rol' nauki", Pravda, March 20, 1986.

"Kliuchevaia rol' nauki", Pravda, Oct. 17, 1986a.

Kolesnikov, A. S., and Obruchnikov, I. V., "Sovershenstvovat' ekspertizu", Ekonomika i organizatsiia promyshlennogo proizvodstva, no. 1, 1979.

Kolesnikov, A. S., and Starovit, V. V., "Stimulirovanie vazhnykh izobretenii", Ekonomika i organizatsiia promyshlennogo proizvodstva, no. 12, 1984.

Komarov, Ie., and V. Usmanov, "`Konstruktory' bumag", Pravda, July 12, 1986.

Kontorovich, F. S., Savel'ev, A.A., Fliorov, L. A., and Iakovlev, V. A., "Issledovanie osnashchennosti NIItekhnicheskimi srtedstvami", Naukovedenie i informatika, no. 9, 1973.

Kontorovich, V., Productivity in the Soviet Economy: Analysis and Prospects for the 1980s. Volume A1. Washington, DC: Foundation for Soviet Studies, June 1985.

Kontorovich, V., "Discipline and Growth in the Soviet Economy", Problems of Communism, Nov.-Dec. 1985a.

Kontorovich, V., "Soviet Growth Slowdown: Econometric vs. Direct Evidence", American Economic Review Papers and Proceedings, May 1986.

Kontorovich, V., "Labor Problems and Policies and Acceleration of Economic Growth", in: Maurice Friedberg and Heyward Isham, eds., Soviet Society Under Gorbachev. Armonk. NY: M. E. Sharpe (forthcoming).

Koriagin, A. G., Plaksia, V. I., and Tsatsunkov, V. V., eds., Sotsialisticheskoe vosproizvodstvo: dimamizm i effektivnost'. Moscow: Mysl', 1983.

Kornai, Janos, "The Hungarian Reform Process: Visions, Hopes, and Reality", Journal of Economic Literature, vol. 24, Dec. 1986.

Korolev, M., "S chem vykhodit v put' NII", Pravda, March 25 and 26, 1984.

Kosov, E. V., Intensifikatsiia nauchnykh issledovanii i razrabotok. Moscow: Ekonomika, 1983.

Kostin, K. F., "Zavodskoi konstruktor: polozhenie, problemy, vozmozhnosti", Ekonomika i organizatsiia promyshlennogo proizvodstva, no. 7, 1983.

Kostin, L. A., Proizvoditel'nost' truda i tekhnicheskii progress. Moscow: Ekonomika, 1974.

Kostin, L. A., "Rubl' na trudovykh vesakh", Pravda, Feb. 17, 1987.
Kovalenko, Vitalii, "Dogoniat'? Net, operezhat'", Sotsialisticheskaia industriia, April 25 and 26, 1986.
Kozhanov, N., "Kinematograf i vremia", Pravda, Aug. 28, 1986.
Kozhevnikova, G., and Shchedrina, T., "Povyshenie effektivnosti nauchnykh issledovanii", Voprosy ekonomiki, no. 10, 1976.
Kozlova, T. Z., and A. G. Kuznetsov, "Vozrastnaia struktura nauchnykh kadrov SSSR: tendentsii i perspektivy", Naukovedenie i informatika, issue 11, 1974.
Kozlova, T. Z., Vozrastnye gruppy v nauchnom kollektive. Moscow: Nauka, 1983.
Krainev, A., and M. Khvostikov, "Izobreteniia ne dlia vnedreniia?", Sotsialisticheskaia industriia, May 29, 1986.
Kratov, Oleg, "O chem dumaet konstruktor pervoi kategorii odnogo KB", Ekonomika i organizatsiia promyshlennogo proizvodstva, no. 4, 1985.
Kresin, Vladimir Z., "The State of Natural Sciences in the USSR. A Physicist's Point of View", Paper # 5 in the "Soviet Science and Technology Eyewitness Accounts" Seminar, Harvard Russian Research Center, Cambridge, MA (no date).
Kruse-Vaucienne, Ursula M., and John M. Logsdon, Science and Technology in the Soviet Union. A Profile. Washington, DC: Graduate Program in Science, Technology, and Public Policy, George Washington University, 1979.
Kudrin, B. I., "Nauchno-tekhnicheskii progress i formirovanie tekhnotsenozov", Ekonomika i organizatsiia promyshlennogo proizvodstva, no. 8, 1980.
Kugel', S. A., "Opyt izucheniia sotsiologicheskikh problem mezhregional'noi migratsii nauchnykh kadrov v SSSR", in: Nauka i tekhnika (voprosy teorii i istorii). issue VII, part I. Leningrad: 1972.
Kugel', S. A., "Mobil'nost' i demograficheskie problemy nauchnykh kadrov", in: Kelle and Mikulinskii, 1974.
Kugel', S. A., and P. B. Shelishch, "Nauchnaia intelligentsiia SSSR: faktory i tendentsii razvitiia", Sotsiologicheskie issledovaniia, no. 1, 1979.
Kugel', S. A., Professional'naia mobil'nost' v nauke. Moscow: Mysl', 1983.
Kulikov, O. A., and R. M. Granovskaia, "Vospitanie myshleniia konstruktora", Ekonomika i organizatsiia promyshlennogo proizvodstva, no. 11, 1985.
"Kursom uskoreniia", Gudok, Apr. 18, 1986.
Kushlin, V. I., Uskorenie vnedreniya nauchnykh dostizhenii v proizvodstvo. Moscow: 1976.
Kushlin, V. I., Intensifikatsiia obnovleniia proizvodstvennogo apparata. Moscow: Mysl', 1986.
Kuznets, Simon, Modern Economic Growth. Rate, Structure and Spread. New Haven, Conn.: Yale University Press, 1966.
"Kvalifikatsionnye kharakteristiki nauchnykh sotrudnikov", Ekonomicheskaia gazeta, no. 17, April 1986.
Kvasha, Ia. B., "Sootnoshenie zatrat na nauku i proizvodstvennykh

kapital'nykh vlozhenii", in: Notkin, A. I., ed., Sotsialisticheskoe nakoplenie. Moscow: Nauka, 1973.

Labutova, T. S., "Zaniatiia naseleniia SSSR", in: Isupov, A. A., and N. Z. Shvartser, eds., Vsesoiuznaia perepis' naseleniia 1979 goda. Moscow: Finansy i statistika, 1984.

La Brie, Rita, and Andrew M. Sessler, "Impact on World Science of Soviet Science as Measured by Journal Citations", Berkeley, CA: Lawrence Berkeley Labcratory, 1983.

Lakhtin, G. A., Upravlenie v nauchnom uchrezhdenii. Moscow: Energoatomizdat, 1983.

Lakhtin, G. A., ed., Osnovy upravleniia naukoi. Moscow: Nauka, 1983.

Lakhtin, G., "Puti intensifikatsii", Pravda, Nov. 15, 1986.

Lebedev, Iu. V., "Aktual'nye voprosy upravleniia otraslevoi naukoi na sovremennom etape", Izvestiia AN SSSR. Seriia ekonomicheskaia. no. 1, 1986.

Lebedev, V. G., Kamankin, V. P., and Poltorygin, V. K., eds., Tekhnicheskii progress i effektivnost' vosproizvodstva osnovnykh fondov. Moscow: Mysl', 1970.

Lebedev, V. G., Narodnokhoziaystvennaya effektivnost' razvitiia tekhniki. Moscow: 1971.

Lebedev, V. G., et al., eds., Nauchno-tekhnicheskaia revoliutsiia i stroitel'stvo kommunizma. Moscow: Mysl', 1976.

Leont'eva, Ie., "Melkotem'e", Sotsialisticheskaia industriia, July 10, 1986.

Leont'eva, Ie., "Illuzii po-nauchnomu", Sotsialisticheskaia industriia, April 10 and 11, 1986a.

Leshchiner, R., "Nauchno-tekhnicheskii potentsial SSSR", Politicheskoe samoobrazovanie, no. 5, 1979.

Letenko, V. A., et al., Ekonomika mashinostroitel'noi promyshlennosti SSSR. Moscow: Mashinostroenie, 1968.

L'ianov, B., "Chto v portfele izobretatelia?", Ekonomicheskaia gazeta, no. 49, Dec. 1985.

Logunov, A., "Effektivnost' tvorchestva", Pravda, July 29, 1985.

Lubrano, Linda L., and Susan G. Solomon, eds., The Social Context of Soviet Science. Boulder, Colorado: Westview Press, 1980.

Lyskov, B. P., "GKNT: analiz obnadezhivaet", Ekonomika i organizatsiia promyshlennogo proizvodstva, no. 1, 1982.

Mansfield, Edwin, ed., Research and Innovation in the Modern Corporation. New York: Norton, 1371.

Mansfield, Edwin, and Wagner, Samuel, "Organizational and Strategic Factors Associated with Probabilities of Success in Industrial R&D", Journal of Business, vol. 48, no. 2, April 1975.

Marek, A. I., and A. I. Semenov, Nauchno-proizvodstvennye kompleksy: formirovanie i razvitie. Moscow: Nauka, 1985.

Marin, L. G., and Pavelko, R. V., "Statisticheskoe izuchenie obnovleniia produktsii mashinostroeniia", in: Akademiia nauk SSSR. Tsentralnyi ekonomiko-matematicheskii institut. Statisticheskie issledovaniia v otrasliakh narodnogo khoziaistva. Moscow: Nauka, 1974.

Martens, John A. and John A. Young, "Soviet Implementation of

Domestic Inventions: First Results", in: US Congress, Joint Economic Committee, Soviet Economy in a Time of Change. vol 1. Washington, DC: Government Printing Office, 1979.

Martens, John A., "Soviet Patents and Inventor's Certificates", in: US Congress, Joint Economic Committee, Soviet Economy in the 1980's: Problems and Prospects. vol 1. Washington, DC: Government Printing Office, 1979.

Marushchak, V. T., and V. A. Iakovlev, "Analiz sostoianiia i osnovnykh putei formirovaniia nauchnogo potentsiala v uchrezhdeniiakh Akademii nauk USSR", Naukovedenie i informatika, issue 25, 1984.

Maskarev, Iu. Ie., "Po leninskomu puti", Voprosy izobretatel'stva, no. 9, 1969.

Matlin, A., Tekhnicheskii progress i tseny mashin. Moscow: Ekonomika, 1966.

Mavliutov, R., "Prestizh inzhenera", Pravda, June 15, 1984.

Medvedev, V., "Rasshiriat' set' mezhotraslevykh ob'edinenii", Ekonomicheskaia gazeta, no. 7, Feb. 1986.

Mel'nikov, E. A., "Inzhenernyi vakuum", Ekonomika i organizatsiia promyshlennogo proizvodstva, no. 10, 1985.

Mikhailov, V., "Nuzhny novye struktury ...", Sotsialisticheskaia industriia, June 3, 1986.

Mikhnevich, Iu. M., Ekonomicheskie problemy upravleniia nauchno-tekhnicheskim progressom. Leningrad: Lenizdat, 1974.

Mindeli, L. E., "Metodologicheskie i metodicheskie problemy issledovaniia nauchnogo potentsiala (resursnyi aspekt)", Izvestiia AN SSSR. Seriia ekonomicheskaia. no. 1, 1986.

Minin, B. A, "Ob otsenke ekonomicheskoi znachimosti izobretenii", Voprosy izobretatel'stva, no. 9, 1976.

Minin, B. A., "Effektivnost' pervoi fazy", Ekonomika i organizatsiia promyshlennogo proizvodstva, no. 1, 1979.

Minin, B. A., "Predlozheniia po reorganizatsii sovetskoi patentnoi sistemy", Ekonomika i organizatsiia promyshlennogo proizvodstva, no. 12, 1980.

"MNTK: shagi stanovleniia", Ekonomicheskaia gazeta, no. 22, May 1986.

"MNTK - maksimum vnimaniia", Pravda, Feb. 8, 1987.

Moroz, Oleg, "Dissertatsiia ... radi chego?", Literaturnaia gazeta, Feb. 5, 1986.

Motorin, I., "Tsena original'nosti", Ekonomicheskaia gazeta, no. 19, May 1979.

Motorygin, B. D., and P. A. Sedlov, Ekonomicheskie problemy sozdaniia novoi tekhniki. Moscow: Mashinostroenie, 1980.

"Nachalas' navigatsiia", Pravda, May 8, 1986.

Naiashkov, I., "Sozdat', chtoby vnedrit'", Sotsialisticheskaia industriia, June 26, 1976.

Naiashkov, I., " ", Pravda, June 30, 1979.

Naiashkov, I. S., "K novym rubezham nauchno-tekhnicheskogo progressa", Voprosy izobretatel'stva, no. 6, 1986.

Nalimov, V. V., and Mul'chenko, Z. M., Naukometriia. Moscow: Nauka, 1969.

Narin, Francis, J. Davidson Frame, and Mark P. Carpenter, "Highly

Cited Soviet Papers: An Exploratory Investigation", Social Studies of Science, vol. 13, 1983.
Natapov, L., "S inzhenera spros osobyi", Pravda, Sept. 23, 1986.
Nedil'ko, V. I., Intensifikatsiia nauki: soderzhanie i planovo-finansovyye faktory. Minsk: Nauka i tekhnika, 1984.
Nekhoroshev, Iu. S., "Nauchno-proizvodstvennyi opyt i mekhanizm ego rasprostraneniia", Ekonomika i organizatsiia promyshlennogo proizvodstva, no. 7, 1979.
Nelson, Richard R., "Assessing private enterprise: an exegesis of tangled doctrine", The Bell Journal of Economics, vol. 12, no. 1, Spring 1981.
Nelson, Richard R., "Research on Productivity Differences: Dead Ends and New Departures", Journal of Economic Literature, no. 3, vol. 19, September 1981a.
Nesterikhin, Iu. Ie., "Energiia novizny", Literaturnaia gazeta, Aug. 21, 1985, p. 10.
Nikitin, A., "Arsenal progressa", Pravda, Oct. 29, 1984.
Nikitin, A., "Inzhenernyi eksperiment", Pravda, April 7, 1986.
Nimitz, Nancy, The Structure of Soviet Outlays on R&D in 1960 and 1968. R-1207 DDRE. Santa Monica, Ca.: Rand Corporation, 1974.
Nolting, Louvan E., "The Financing of Research, Development, and Innovation in the USSR, by Type of Performer", Foreign Economic Report no. 9. Washington, DC: US Department of Commerce, Bureau of the Census, April 1976.
Nolting, Louvan E., "The 1968 Reform of Scientific Research, Development, and Innovation in the USSR", Foreign Economic Report no. 11, Washington, DC: US Department of Commerce, Bureau of the Census, September 1976a.
Nolting, Louvan E., "The Planning of Research, Development, and Innovation in the USSR", Foreign Economic Report no. 14, Washington, DC: US Department of Commerce, Bureau of the Census, July 1978.
Nolting, Louvan E., "The Structure and Functions of the USSR State Committee for Science and Technology", Foreign Economic Report no. 16, Washington, DC: US Department of Commerce, Bureau of the Census, November 1979.
Nolting, Louvan E., "Financing of Research, Development, and Innovation in the USSR", Foreign Economic Report no. 22, Washington, DC: US Department of Commerce, Bureau of the Census, September 1985.
Nolting, Louvan E., and Murray Feschbach, Statistics on Research and Development Employment in the USSR. International Population Reports, Series P-95, no. 76. Washington, DC: Bureau of the Census, June 1981.
Noren, James, "Soviet Investment Strategy Under Gorbachev", paper presented at the 18th National Convention of the AAASS, New Orleans, Nov. 1986.
Nove, A., "Problem of 'Success Indicators' in Soviet Industry", Economica, Feb. 1958.
"Ob osnovnykh napravleniiakh ekonomicheskogo i sotsial'nogo razvitiia SSSR na 1986-1990 gody i na period do 2000 goda",

Pravda, March 4, 1986.
Obraztsov, I. F., "Nauchnyi potentsial vysshei shkoly", Pravda, Nov. 10, 1981.
Obraztsov, I. F., "Ispol'zovanie nauchnogo potentsiala vysshei vuzov", Voprosy ekonomiki, no. 7, 1986.
Obukhov, V., "Izobresti i ispol'zovat'", Pravda, Jan. 7, 1986.
"Ob uluchshenii planirovaniia i usilenii vozdeistviia khoziaistvennogo mekhanizma na povyshenie effektivnosti proizvodstva i kachestva raboty", decree of the CC CPSU and Council of Ministers of the USSR of July 12, 1979, in: Sovershenstvovanie khoziaistvennog mekhanizma. 2nd ed. Moscow: Pravda, 1982.
OECD. OECD Science and Technology Indicators. Resources Devoted to R&D. Paris: OECD, 1984.
Orlov, A., "Sozdanie vysokoeffektivnoi tekhniki", Voprosy ekonomiki, no. 1, 1986.
"Osnovnye napravleniia ekonomicheskogo i sotsial'nogo ravitiia SSSR na 1986-1990 gody i na period do 2000 goda", Pravda, March 9, 1986.
"Osnovnye napravleniia perestroiki vysshego i srednego spetsial'nogo obrazovaniia v strane", Pravda, June 1, 1986.
Pakes, Ariel, and Griliches, Zvi, "Patents and R&D at the Firm Level: A First Look", in: Griliches, 1984.
Pakes, Ariel, and Schankerman, Mark, "The Rate of Obsolescence of Patents, Research Gestation Lags, and the Private Rate of Return to Research Resources", in: Griliches, 1984.
Palterovich, D. M., "Osobennosti razvitiia orudii truda v period nauchno-tekhnicheskoi revoliutsii", Izvestiia Akademii Nauk SSSR. Seriia ekonomicheskaia. no. 4, 1979.
Palterovich, D. M., "Ekonomiia orudii truda", Kommunist, no. 10, 1984.
Paolillo, Joseph J., and Brown, Warren B., "How Organizational Factors Affect R&D Innovation", Research Management, no.2, March 1978.
Parfionov, Vasilii, "Chelovecheskii faktor", Pravda, May 20, 1985a.
Parfionov, Vasilii, "Veter - v parusa", Pravda, Oct. 28, 1985.
Parkhomenko, A. I., "Skol'ko planov u NPO", Ekonomicheskaia gazeta, no. 34, Aug. 1986.
Parrott, Bruce, "The Organizational Environment of Soviet Applied Research", in: Lubrano and Solomon, 1980.
Parrott, Bruce, Information Transfer in Soviet Science and Engineering. A Study of Documentary Channels. R-2667-ARPA. Rand Corporation: Santa Monica, CA, 1981.
"Piatiletke - kachestvo i tempy", Pravda, Jan. 18, 1987.
Piekarz, Rolf, Eleanor Thomas, and Donna Jennings, "International Comparisons of Research and Development Outlays and Indicators of Technological Progress", in: John W. Kendrick, ed., International Comparisons of Productivity and Causes of Slowdown. Cambridge, MA: Ballinger, 1984.
Pirogov, S. V., Upravlenie naukoi. Moscow: Mysl', 1983.
"Pochemu stareiut 'molodye uchenye'?", Literaturnaia gazeta,

March 27, 1985.
Pokhodnia, I., "Nauka boretsia s poteriami", Pravda, Feb. 4, 1986.
Pokrovskii, V. A., "Ukrupnennye normativy prognozirovaniia effektivnosti NIOKR dlia razlichnykh ierarkhicheskikh urovnei upravleniia", Naukovedenie i informatika no. 18, 1977.
Pokrovskii, V. A., Povyshenie effektivnosti nauchnykh issledovanii i razrabotok. Moscow: Ekonomika, 1978.
Pokrovskii, V. A., Uskorenie nauchno-tekhnicheskogo progressa. Moscow: Ekonomika, 1983.
Polianskii, Anatolii, "Plody psikhologii monopolistov", Literaturnaia gazeta, Oct. 1, 1986.
"Politicheskii doklad Tsentral'nogo Komiteta KPSS XXVII s'ezdu Kommunisticheskoi partii Sovetskogo Soiuza", Pravda, Feb. 26, 1986.
Popov, L., "Shipy v lavrakh", Pravda, Feb. 3, 1986.
Popovskii, Mark, Manipulated Science. Garden City, New York: Doubleday & Company, Inc., 1979.
Poshekhonov, Iu. V., "Metodologicheskie problemy tipologii nauchnykh kollektivov", Sotsiologicheskie issledovaniia, no. 4, 1978.
Povoliaev, Valerii, "Zagliadyvaia v zavtra", Pravda, Dec. 31, 1985.
Prokhorov, A., "Iz arsenala fiziki", Pravda, July 9, 1986.
Prokhorov, V., "Uravnenie s bakenbardami", Pravda, May 13, 1985.
Pugacheva, A., and Zam, L., "Effekt issledovanii", Gudok, July 8, 1986.
Puchkov, I. S., and G. A. Popov, Sotsial'no-demograficheskaia kharakteristika nauchnykh kadrov. Moscow: Statistika, 1976.
Pushkarev, G. A., "Chto nuzhno konstruktoru ot NTI?", Ekonomika i organizatsiia promyshlennogo proizvodstva, no. 9, 1984.
Pushkarev, G. A., "Anatomiia konstruktorskogo prestizha", Ekonomika i organizatsiia promyshlennogo proizvodstva, no. 6, 1986.
"Rabota i zarabotok v vuze", Literaturnaia gazeta, Nov. 26, 1986.
Rapoport, John, "The Anatomy of the Product-Innovation Process: Cost and Time", in: Mansfield, 1971.
Rassokhin, V. P., "Nuzhna chetvertaia sistema nauchnykh uchrezhdenii", Ekonomika i organizatsiia promyshlennogo proizvod stva, no. 1, 1980.
Rassokhin, V. P., "Novatorstvo, vedomstvennost i pravo", Ekonomika i organizatsiia promyshlennogo proizvodstva, no. 2, 1984.
Rassokhin, V. P., Mekhanizm vnedreniia dostizhenii nauki. Moscow: Nauka, 1985.
"Rech' tovarishcha Aleksandrova A. P.", Pravda, Feb. 27, 1986.
"Rech' tovarishcha Dinkova V. A.", Pravda, March 3, 1986.
"Rech' tovarishcha Frolova K. V.", Pravda, March 4, 1986.
"Rech' tovarishcha Konareva N. S.", Pravda, March 4, 1986.
"Rech' tovarishcha Patona B. E.", Pravda, March 5, 1986.
"Rech' tovarishcha Shkabardni M. S.", Pravda, Feb. 27, 1986.

"Rech' tovarishcha Sozinova A. A.", Pravda, March 6, 1986.
"Rech' tovarishcha Usmanova G. I.", Pravda, March 3, 1986.
Reut, Viktor, "Sdelano izobretenie", Pravda, Sept. 16, 1985.
Riabov, S., "Iesli budete nadoedat' ...", Pravda, May 14, 1986.
Riabushkin, T. V., Sotsial'nye i ekonomicheskie problemy povysheniia effektivnosti nauki. Moscow: Nauka, 1985.
Rudich, F., "Nauchnye tsentry akademii", Pravda, July 2, 1985.
Rudoi, M., "Priamoi kontakt", Sotsialisticheskaia industriia, June 3, 1986.
Rutgaizer, V. M., Resursy razvitiia neproizvodstvennoi sfery. Moscow: Mysl', 1975.
Ryzhkov, N. I., O Gosudarstvennom plane ekonomicheskogo i sotsial'nogo razvitiia SSSR na 1986-1990 gody. Moscow: Politizdat, 1986.
Sadovnichaia, S. G., and Shevchenko-Marsel', V. I., Organizatsiia razrabotok novoi tekhniki. L'vov: Vyshcha shkola, 1985.
Samoilov, G. A., "Problema normirovaniia nauchnogo truda", Naukovedenie i informatika, issue 7, 1972.
Sbornik normativnykh aktov po izobretatel'stvu i ratsionalizatsii. Moscow: Iuridicheskaia literatura, 1983.
Scherer, Frederic M., "Comment", in: Griliches, 1984.
Semykin, N. and Bocharov, V., "Glavnyi kriterii", Sotsialisticheskaia industriia, April 29, 1986.
Serov, N. K., "O sovershenstvovanii statisticheskogo ucheta nauchnykh kadrov SSSR", in: Nauka i tekhnika (voprosy teorii i istorii). issue VII, part I. Leningrad, 1972.
Shalgunov, V., "Peizazh s pripiskoi", Pravda, July 6, 1986.
Sheinin, Iu., "Usloviia nauchnogo truda", in: Nauka v sotsial'nykh, gnoseologicheskikh i tsennostnykh aspektakh. Moscow: Nauka, 1980.
Shemiakin, Ie., "Sibir' gornaia", Pravda, Sept. 2, 1986.
Shchelishch, P. B., Dinamika nauki. Leningrad: Nauka, 1981.
Shcherbakov, A. I., Sotsial'no-ekonomicheskie problemy effektivnosti nauchnogo truda. Novosibirsk: Nauka, 1975.
Shcherbakov, A. I., Effektivnost' nauchnoi deiatel'nosti v SSSR. Moscow: Ekonomika, 1982.
Shimanovich, M. A., "Chem deshevle - tem dorozhe", Ekonomika i organizatsiia promyshlennogo proizvodstva, no. 6, 1986.
Shkabardnia, M., "Uskorenie nauchno-tekhnicheskogo progressa v mashinostroenii", Voprosy ekonomiki, no. 1, 1986.
Shlapentokh, Vladimir, Life Goals of the Soviet People. New York: Oxford University Press, forthcoming.
Shukshinov, V. E., "Dlia otrabotki idei", Ekonomicheskaia gazeta no. 16, Apr. 1986.
Siemaszko, Z. A., "Industrial process control", in: Amann, Cooper, and Davies, 1977.
Siemaszko, Z. A., "Control instrumentation for industrial processes", in: Amann and Cooper, 1982.
Silaev, I., "Mashinostroenie - osnova rekonstruktsii", Sotsialisticheskaia industriia, June 24, 1986.
"Snabzheniu - gibkost', ekonomichnost, ritm", Ekonomicheskaia gazeta no. 17, Apr. 1986.

Sokolov, B., "Sterzhen' progressa - klassnyi spetsialist", Literaturnaia gazeta, Nov. 13, 1985.
Sokolov, B. S., and Reimers, N. F., "Effektivnye formy upravleniia naukoi", Ekonomika i organizatsiia promyshlennogo proizvodstva, no. 9, 1983.
Sominskii, V. S., and Torf, E. M., "Sostav i struktura kadrov v sfere nauki i nauchnogo obsluzhivaniia", Naukovedenie i informatika no. 6, 1972.
Sominskii, V. S., "NTP: 'zri v koren'...`", Ekonomika i organizatsiia promyshlennogo proizvodstva, no. 7, 1986.
"Sovet partii s narodom", Pravda, Sept. 19, 1986.
Struninskii, "Ataka na bar'ery", Literaturnaia gazeta, Sept. 18, 1985.
Subbotina, G. V., Iu. A. Selishchev, and A. G. Kuznetsov, "Primenenie kolichestvennykh metodov pri provedenii sotsiologicheskikh issledovanii dlia tselei sotsial'nogo planirovaniia v NII", in: A. A. Zvorykin, ed., Problemy sotsial'nogo planirovaniia v nauchnom kollektive. Issue I. Moscow: ISI, 1976.
Sutton, A. S., Western Technology and Soviet Economic Development. 3 vols. Stanford, Ca.: Hoover, 1968-1973.
Taksir, K. I., Sushchnost' i formy soedineniia nauki s proizvodstvom pri sotsialiszme. Moscow: Vysshaya shkola, 1974.
Tarasov, A., "Priznanie oshibki", Pravda, July 19, 1986.
Tarasov, A., "Zatory na magistrali", Pravda, Nov. 4, 1986a.
"Tekhnicheskaia dokumnetatsiia i standarty", Ekonomicheskaia gazeta, no. 17, Apr. 1986.
"Tekhnicheskii proryv v budushchee", Ekonomika i organizatsiia promyshlennogo proizvodstva, no. 2, 1986.
"Tekhnologicheskii proryv v budushchee", Ekonomika i organizatsiia promyshlennog proizvodstva, no. 2, 1986.
"Tema, vzvolnovavshaia mnogikh", Ekonomika i organizatsiia promyshlennogo proizvodstva, no. 4, 1985.
Totskii, I., "Kem rabotat' inzheneru?", Pravda, Feb. 17, 1986.
Trapeznikov, V., "Skazka o gnomakh", Pravda, Jan. 8, 1987.
"Trevozhnye tendentsii: snizhenie pokazatelei", Izobretatel' i ratsionalizator, no. 7, 1983.
Tsentral'noe Statisticheskoe Upravlenie pri Sovete Ministrov SSSR. Itogi vsesoiuznoi perepisi naseleniia 1959 goda. SSSR (svodnyi tom). Moscow: Gosstatizdat, 1962.
Tsentral'noe Statisticheskoe Upravlenie pri Sovete Ministrov SSSR. Itogi vsesoiuznoi perepisi naseleniia 1970 goda. vol. VI. Moscow: Statistika, 1973.
Tsentral'noe Statisticheskoe Upravlenie pri Sovete Ministrov SSSR. Kul'turnoe stroitel'stvo v SSSR. Moscow: Gosudarstvennoe statisticheskoe izdatel'stvo, 1956.
Tsentral'noe Statisticheskoe Upravlenie pri Sovete Ministrov SSSR. Narodnoe obrazovanie, nauka i kul'tura v SSSR. Moscow: Statistika, 1971.
Tsentral'noe Statisticheskoe Upravlenie pri Sovete Ministrov SSSR. Promyshlennost' SSSR. Moscow: Statistika, 1964.
Tsentral'noe Statisticheskoe Upravlenie pri Sovete Ministrov

SSSR. Trud v SSSR. Moscow: Statistika, 1968.
Tsigel'nik, A. M., "O metodologii i praktike statisticheskogo izucheniia obnovleniia promyshlennoi produktsii", in: Akademiia nauk SSSR. Tsentral'nyi ekonomiko-matematicheskii institut. Problemy statistiki tekhnicheskogo progressa v promyshlennosti. Moscow: Nauka, 1971.
Tursunov, A., "Potentsial nauki", Pravda, Aug. 3, 1986.
Tverdokhleb, V. A., and Bialik, B. M., Naukovedenie i informatika, issue 25, 1984.
Ulitskii, A. I., Tekhnicheskii progress i ekonomika predpriiatiia. Moscow: Mashinostroenie, 1980.
Ushanov, S., "Nichto, prikinuvsheesia metallom", Literaturnaia gazeta, June 25, 1986.
Uvarova, L. I., Nauchnyi progress i razrabotka tekhnicheskikh sredstv. Moscow: Nauka, 1973.
Varavka, V., "O chem mychal Sudar'?", Pravda, Jan. 5, 1986.
Varshavskii, K. M., "K voprosu ob izuchenii professional'noi struktury kadrov nauki", Naukovedenie i informatika, no. 5, 1972.
Varshavskii, K. M., "O nauchno-rukovodiashchem personale", Naukovedenie i informatika, no. 6, 1972a.
Vashchenko, V., "Nauka: neibezhnost' perestroiki", Literaturnaia gazeta, June 4, 1986.
Vasil'ev, Iu., "'Eksperiment' s eksperimental'nymi tsekhami", Ekonomicheskaia gazeta, no. 33, Aug. 1979.
Vasin, M., "Nadezhnost' mashin", Pravda, June 23, 1986.
Viunitskii, V., "Planirovat' poisk", Pravda, Dec. 17, 1985.
"Vklad novatorov", Pravda, March 29, 1985.
"V Komitete Partiinogo Kontrolia pri TsK KPSS", Pravda, July 9, 1986.
Volkov, O. I., Planovoe upravlenie nauchno-tekhnicheskim progressom. Moscow: Nauka, 1975.
Volovich, L. M., "K voprosu vliianiia moral'nogo iznosa na sroki sluzhby nekotorykh vidov nauchnogo oborudovaniia", Naukovedenie i informatika, issue 13, 1975.
Vorob'ev, Kh., "Mashiny dlia otrasli", Pravda, Aug. 21, 1986.
Voronov, Iu. P., "Ikh prava - vsem vo blago", Ekonomika i organizatsiia promyshlennogo proizvodstva, no. 7, 1984.
"V Politburo TsK KPSS", Pravda, Jan. 23, 1987.
"V Sovete Ministrov SSSR", Pravda, June 27, 1986.
"V Tsentral'nom Komitete KPSS i Sovete Ministrov SSSR", Ekonomicheskaia gazeta, no. 36, Sept. 1983.
"V Tsentral'nom Komitete KPSS i Sovete Ministrov SSSR", Pravda, July 2, 1986.
"V TsK KPSS, Sovete Ministrov SSSR i VTsSPS", Ekonomicheskaia gazeta, no. 29, July 1985.
"V vikhre idei", Ekonomika i organizatsiia promyshlennogo proizvodstva, no. 4, 1982.
Vyzhutovich, V., "Protektsiia", Literaturnaia gazeta, April 2, 1986.
"Vzyskatel'nost' - rezerv uskoreniia", Pravda, June 4, 1986.
Wagner, Leonore U., "Problems in Estimating Research and Develop-

ment Investment and Stock", in: The Proceedings of the Business and Economic Statistics Section. Washington, DC: American Statistical Association, 1968.

Yankevich, W. F., "Analysis of Publication and Invention Productivity in Some Soviet Academic Institutions", Scientometrics, vol. 4, no. 6, 1982.

Zabulis, G., "Perekrestki perestroiki", Pravda, Jan 7, 1987.

Zaikov, L. N., "Rabotat' initsiativno, energichno", Pravda, Oct. 30, 1986.

Zaleski, E., et al., Science Policy in the USSR. Paris: OECD, 1969.

"Za ramkami vedomstvennykh interesov", Ekonomicheskaia gazeta, no. 12, March 1986.

"Za stepen' - prosto, za trud - slozhno", Literaturnaia gazeta, May 14, 1986.

Zavlin, P. N., Shcherbakov, A. I., and Iudelevich, M. A., Trud v v sfere nauki. Moscow: Ekonomika, 1973.

Zavlin, P. N., and Iudelevich, M. A., Nauchnyi trud v usloviiakh NTR: effektivnost' i kachestvo. Moscow: Ekonomika, 1985.

Zhamin, V. A., Nauka i ekonomika sotsializma. Moscow: Mysl', 1971.